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ELECTRIC TELEGRAPHS.[1]

By Prof. A. P. DESCHANEL.

THE discovery that electricity could be transmitted instantaneously to great distances at once suggested the idea of employing it for signalling. Bishop Watson performed several experiments of this kind in the neighborhood of London, the most remarkable being the transmission of the discharge of a Leyden jar through 10,600 feet of wire suspended between wooden poles at Shooter's Hill. This was in 1747. A plan for an alphabetical telegraph to be worked by electricity is minutely described in the *Scot's Magazine* for 1753, but appears to have been never experimentally realized. Lesage, in 1774, erected at Geneva a telegraph-line, consisting of twenty-four wires connected with the same number of pith-ball electroscopes, each representing a letter. Reusser, in Germany, proposed, in the same year, to replace the electroscopes by spangled panes exhibiting the letters themselves. The difficulty of managing frictional electricity was, however, sufficient to prevent these and other schemes founded on its employment from yielding any useful results. Volta's discoveries, by supplying electricity of a kind more easily retained on the conducting wires, afforded much greater facilities for transmitting signals to a distance.

Several suggestions were made for receiving-apparatus to exhibit the effects of the currents transmitted from a voltaic battery. Sömmering, of Munich, in 1811, proposed a telegraph, in which the signals were given by the decomposition of water in thirty-five vessels, each connected with a separate telegraph-wire. Ampère, in 1820, proposed to utilize Œrsted's discovery by employing twenty-four needles, to be deflected by currents sent through the same number of wires; and Baron Schilling exhibited, in Russia, in 1832, a telegraphic model, in

[1] Abridged from Deschanel's "Natural Philosophy," Part III.: "Electricity and Magnetism."

which the signals appear to have been given by the deflections of a single needle. Sir Francis Ronalds, before 1823, sent intelligible messages through more than eight miles of wire insulated and suspended in the air. His elementary signal was the divergence of the pith-balls of a Canton's electrometer produced by the communication of a statical charge to the wire. He used synchronous rotation of lettered dials at each end of the line, and charged the wire at the sending end whenever the letter to be indicated passed an opening provided in a cover; the electrometer at the far end then diverged, and thus informed the receiver of the message which letter was designated by the sender. The dials never stopped, and any slight want of synchronism was corrected by moving the cover.

Weber and Gauss carried out Schilling's plan in 1833 by leading two wires from the Observatory of Göttingen to the Physical Cabinet, a distance of about 9,000 feet. The signals consisted in small deflections of a bar-magnet, suspended horizontally with a mirror attached, on the plan since adopted in Thomson's mirror galvanometer.

At their request, the subject was earnestly taken up by Prof. Steinheil, of Munich, whose inventions contributed more perhaps than those of any other single individual to render electric telegraphs commercially practicable. He was the first to ascertain that earth-connections might be made to supersede the use of a return wire. He also invented a convenient telegraphic alphabet, in which, as in most of the codes since employed, the different letters of the alphabet are represented by different combinations of two elementary signals. Two needles were employed, one or the other of which was deflected according as a positive or a negative current was sent, the deflections being always to the same side. Sometimes the needles were merely observed by eye, sometimes they were made to strike two bells, and sometimes to produce dots, by means of capillary tubes charged with ink, on an advancing strip of paper, thus leaving the permanent record on the strip in the shape of two rows of dots. His currents were magneto-electric, like those of Weber and Gauss.

The attraction of an electro-magnet on a movable armature furnishes another means of signalling. This was the foundation of Morse's telegraphic system, and was employed by Wheatstone for ringing a bell to call attention before transmitting a message.

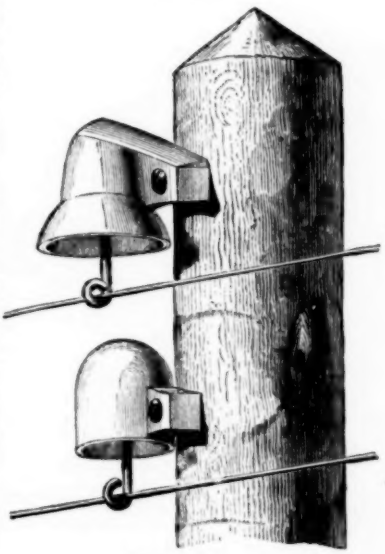
About the year 1837 electric telegraphs were first established as commercial speculations in three different countries. Steinheil's system was carried out at Munich, Morse's in America, and Wheatstone and Cooke's in England. The first telegraphs ever constructed for commercial use were laid down by Wheatstone and Cooke on the London & Birmingham and Great Western Railways. The wires, which were buried in the earth, were five in number, each acting on a separate needle; but the expensiveness of this plan soon led to its being given up. The single-needle and double-needle telegraphs of

the same inventors have been much more extensively used, the former requiring only one wire, and the latter two.

All public telegraphs have now for many years been worked by voltaic currents; the magneto-electric system, which was tried on some lines, having been found to involve a needless expenditure of labor.

According to Mr. Culley, engineer-in-chief to the post-office, the battery which had been adopted by the authorities of that department is a modified Daniell's, consisting of a teak trough, divided into cells by plates of glass or slate, and well coated with marine glue, each cell being divided into two by a slab of porous porcelain. The zinc plates measure four inches by two, and the copper plates, which are very thin, are four inches square. The zinc hangs at the upper part of its cell, which is filled with dilute solution of sulphate of zinc. The copper cell is filled with a saturated solution of sulphate of copper, and crystals of this salt are placed at the bottom. The expenditure in sulphate of copper is about a pound and a half for each cell per annum.

FIG. 1.



INSULATORS.

The wires for land-telegraphs are commonly of what is called galvanized iron, that is, iron coated with zinc, supported on posts by means of glass or porcelain insulators, so contrived that some part of the porcelain surface is sheltered from rain, and insulates the wires from the posts, even in wet weather. Wires thus suspended are called *air-lines*.

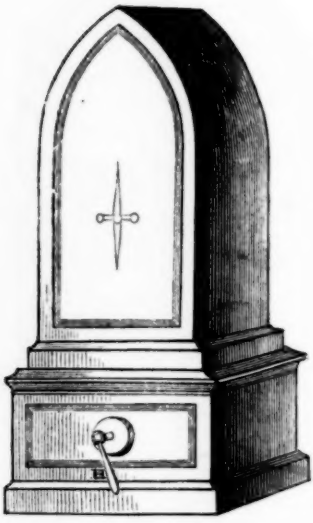
Underground wires are, however, sometimes employed. They are insulated by a coating of gutta-percha, and are usually laid in pipes, an arrangement which admits of their being repaired or renewed without opening the ground except at the drawing-in boxes. There is less leakage of electricity from subterranean than from air lines, but their cost is greater, and they are less suited for rapid signalling on account of the retardation caused by the inductive action between the wire and the conducting earth, which is similar to that between the two coatings of a Leyden jar.

The early inventors of electric telegraphs supposed that a current could not be sent from one station to another without a return-wire to complete the circuit. Steinheil, while conducting experiments on a

railway, with the view of ascertaining whether the rails could be employed as lines of telegraph, made the discovery that the earth would serve instead of a return-wire, and with the advantage of diminished resistance; the earth, in fact, behaving like a return-wire of infinitely great cross-section, and therefore of no resistance.

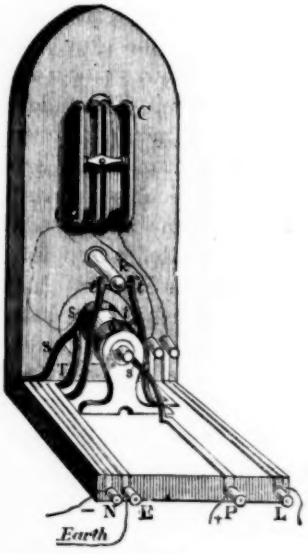
We are not, however, to suppose that the current really returns from the receiving to the transmitting station through the earth. The duty actually performed by the earth consists in draining off the op-

FIG. 2.



SINGLE-NEEDLE INSTRUMENT.

FIG. 3.



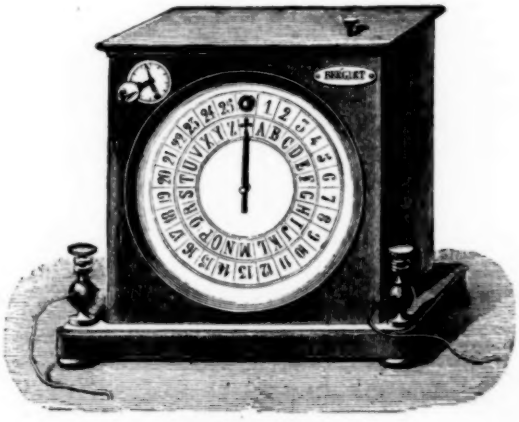
INTERNAL ARRANGEMENTS.

posite electricities which would otherwise accumulate in the terminals. It keeps the two terminals at the same potential; and, as long as this condition is fulfilled, the current will have the same strength as if the terminals were in actual contact.

One of the best-known telegraphs in England, though little or not at all employed elsewhere, is the single-needle instrument of Wheatstone and Cooke, represented in Figs. 2 and 3, the former showing its external appearance, and the latter its internal arrangements as seen from behind. The needle, which is visible in front, is one of an astatic pair, its fellow being in the centre of the coil (C C). When the handle (H) hangs straight down, the instrument is in the position for receiving signals from another station. The current from the line-wire enters at L, and, after traversing the coil and deflecting the needle, escapes through the earth-wire (E), having taken in its course the two tall contact-springs (*t t'*).

To send a current to another station, the handle (H) is moved to one side, and the current sent will be positive or negative according to the side to which the handle is moved. The handle turns the cylindrical arbor (*a b*), which is divided electrically into two parts by an insulator in the middle of its length. Each of these parts has a pin projecting from it, one pin being above, and the other below. These are vertical when the handle is vertical, and are then doing no duty; but, when the handle is put to one side, the upper pin (which is attached to *b*) makes contact with one of the tall springs (*t t'*), at the same time pushing it away from the metallic rest (*k*), and thus putting it out of connection with the other tall spring; while the lower pin (which is attached to *a*) makes contact with one of two short springs (T T'), only one of which is shown in the figure. There is permanent connection between *a* and the negative pole of the battery through the spring *s*, and between *b* and the positive pole through the spring *s'*. In the position represented in the figure, *a* serves to connect the negative pole of the battery with the earth, and *b* serves to connect the positive pole with the spring *t'*, down which the current passes from the point of contact of the pin, and then through the coil to the line-wire at L. The needle of the sending station is thus deflected to the same side as that of the receiving station.

FIG. 4.



BREGUET'S INDICATOR.

If the handle were moved to the other side, *b* would serve to connect the positive pole with the earth, and *a* would establish connection between the negative pole and the coil, which is itself connected with the line-wire.

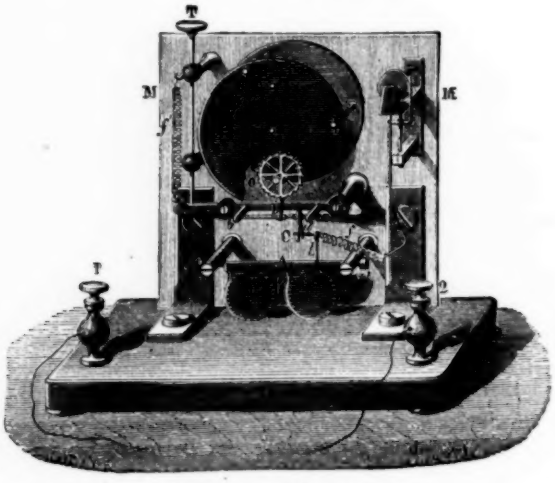
Since the English telegraphs came into the hands of the post-office, the alphabet devised by Wheatstone and Cooke has been given up, and the Morse alphabet, which we give in a later section, adopted in its

place. In the Morse alphabet, which is now the telegraphic alphabet of all nations, the shortest signs are allotted to those letters which occur most frequently. This was not the case with the old needle-alphabet, which was rather planned with the view of assisting the memory; and experience has shown that such assistance is quite unnecessary. The needle instrument is also, to a great extent, being superseded by Morse's instrument.

Telegraphs in which the ordinary letters of the alphabet are ranged round the circumference of a dial, and are pointed at by a revolving hand, are specially convenient for those who are not professional telegraphists. They are constructed on the principle of step-by-step motion, the hand being advanced by successive steps, each representing one current sent or stopped.

One of the simplest instruments of this class is Breguet's, which is extensively used on the French railways. Fig. 4 represents the exterior of the receiving instrument. The dial is inscribed with the 25 letters of the French alphabet and a cross, making 26 signals in all. The hand (as in other step-by-step telegraphs) advances only in one direction, which is the same as that of the hands of a clock, stopping before each letter which is to be indicated, and pointing to the cross at the end of each word. Fig. 5 shows the mechanism by which the

FIG. 5.



MECHANISM OF INDICATOR.

motion is produced. A is the armature of an electro-magnet, the magnet itself being removed in the figure to allow the other parts to be better seen. The two dotted circles traced on the armature represent vertical sections of the two coils, which rest on the bottom of the box, and have their axes horizontal. If introduced, they would nearly con-

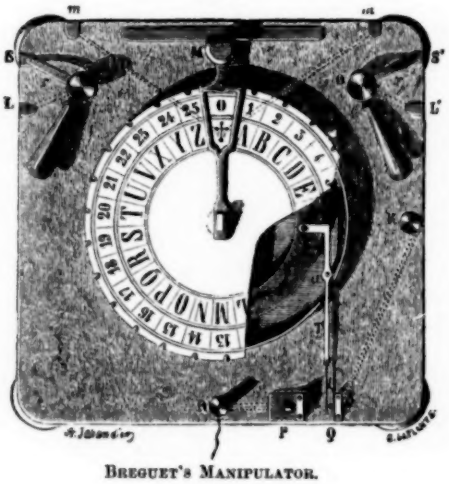
ceal the armature from view. The armature turns about an horizontal axis (V V'), and is attached to an opposing spring which draws it back from the magnet. The tension of this spring can be regulated by means of a lever acted on by a key outside the box. When a current is sent, the armature is attracted to the magnet; when the current ceases, the spring draws it back; and it thus moves continually to and fro during the transmission of a message. An upright arm (*l*) is attached to the armature, and carries an horizontal arm (*c*), which lies between the two prongs of a fork (*d*), represented on a larger scale in Fig. 6. This fork vibrates about an horizontal axis (*a b*), to which is attached the vertical pallet (*i*). This pallet acts upon an escapement-wheel (O), toothed in a peculiar way, the thickness of the teeth being only half the thickness of the wheel, and the teeth on one-half of the thickness being opposite the spaces on the other half. The total number of teeth is 26, thirteen on each half of the thickness.

Fig. 6.

Escapement.

When no current is passing, the pallet (*i*) is engaged with one of the teeth on the remote side, as represented in Fig. 6. When a current passes, the armature is attracted, and the pallet is moved over to

Fig. 7.



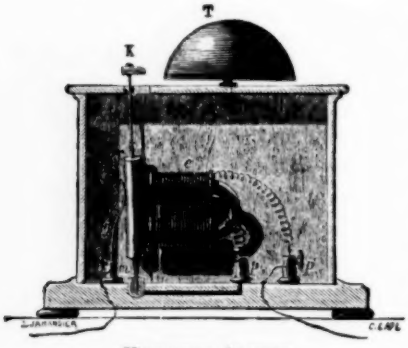
Breguet's Manipulator.

the near side, thus releasing the tooth with which it was previously engaged, and becoming engaged with the next tooth on the near side of the wheel. The wheel, which is urged by a clock-movement, thus advances $\frac{1}{26}$ of a revolution; and the hand on the dial, being attached to the wheel, moves forward one letter. When the current ceases, the

pallet moves back to the remote side, and the hand is advanced another letter. If the hand is initially at the cross, it will be advanced to any required letter by so arranging matters that the number of currents *plus* the number of interruptions shall be equal to the number denoting the place of the letter in the alphabet. To effect this arrangement is the office of the sending instrument.

This is represented in Fig. 7. There is a dial inscribed with 25 letters and a cross, like that of the receiving instrument, and an arm which can be carried round the dial by a handle (M). There are 26 notches cut in the edge of the dial, in which a pin attached to the movable arm catches; and the arm is allowed sufficient play to and from the face of the dial to admit of this pin being easily released or inserted. When the pin is in one of the notches, the instrument is in position for transmitting the corresponding letter. The action is as follows:

FIG. 8.



VIBRATING ALARUM.

A toothed or rather undulated wheel is fixed on the same axis as the revolving arm, and turns with it. There are 13 projections and 13 hollows on its circumference, a few of which are shown in the figure where the face is cut away. A bent lever (T), movable about an axis at *a*, bears at one end against the circumference of the undulated wheel, while its other end plays between two points (P, Q), and is in contact with one or other of these points whenever its upper end bears against a hollow or a projection. P is in connection with a battery, and Q with the earth, the undulated wheel being in connection with the line-wire. The movement of the handle thus produces the requisite number of currents and interruptions.

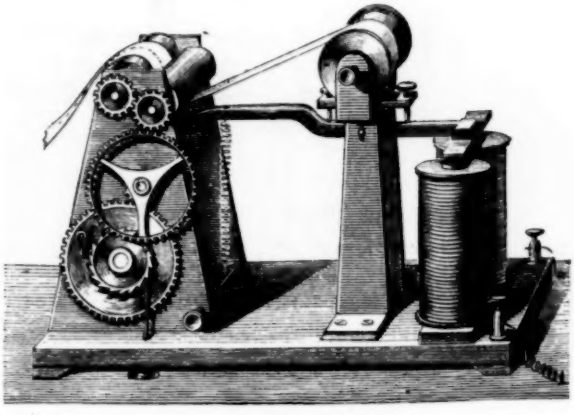
Besides the sending and receiving apparatus above described, each station has an *alarum*, which is employed to call attention before sending a dispatch. There are several different kinds. Fig. 8 represents the *vibrating alarum*, which is one of the simplest. It contains an electro-magnet (*e*), with an armature (*f*), fixed to the end of an elastic plate. When no current is passing through the coil, the armature is held back by the elasticity of this plate, so as to press against a contact-spring (*g*) connected with the binding-screw (*m*). The terminals of the coil are at the binding-screws (*p*, *p'*), the former of which is in connection with the armature, and the latter with the earth. As long as the armature presses against the spring (*g*), there is communication between the two binding-screws (*m* and *p'*) through the coil; but the passing of a current produces attraction of the armature, which draws

it away from *g*, and interrupts the current. The electro-magnet is thus demagnetized, and the armature springs back against *g*, so as to allow a fresh current to pass. The armature is thus kept in continual vibration; and a hammer (K), which it carries above, produces repeated strokes on a bell (T).

Morse's apparatus, first tried in America about 1837, is now perhaps the most extensively used of all.

His receiving instrument, or *indicator*, in its primitive simplicity, consists (Fig. 9) of an electro-magnet, a lever movable about an axis, carrying a soft-iron armature at one end, and a pencil at the other, and a strip of paper which is drawn past the pencil by a pair of rollers.

FIG. 9.



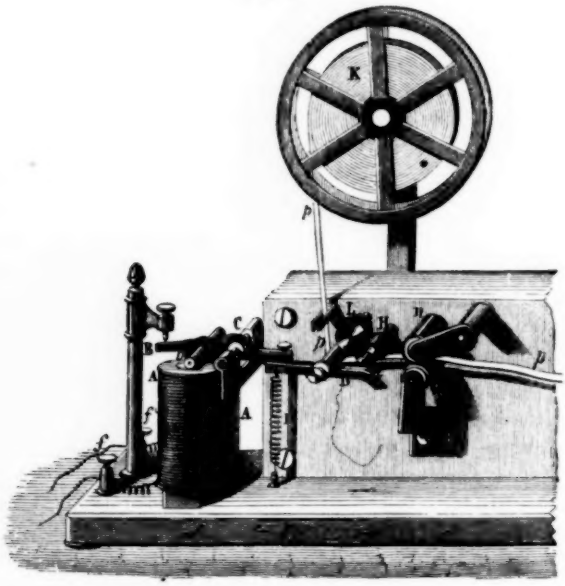
MORSE'S TELEGRAPH.

As the pencil soon became blunt, and was uncertain in its marking, a point, which scratched the paper, was substituted. This has now, to a great extent, been superseded by an ink-writer, which requires the exertion of less force, and at the same time leaves a more visible trace.

Fig. 10 represents Morse's indicator as modified by Digney. A train of clock-work, not shown in the figure, drives one pair of rollers (*n m*), which draw forward a strip of paper (*p p*) forming part of a long roll (K). The same train turns the printing-cylinder (H), the surface of which is kept constantly charged with a thick, greasy ink by rolling-contact with the ink-pad (L). The armature (B B') of the electro-magnet (A) is mounted on an axis at C, and carries a style at its extremity just beneath the printing-cylinder. When a current passes, the armature is attracted, and the style presses the paper against the printing-cylinder, causing a line to be printed on it, the length of which depends on the duration of the current, as the paper continues to advance without interruption. The lines actually em-

ployed are of two lengths, one being made as short as possible (-), and called a *dot*, and the other being about three times as long (—), and called a *dash*. The opposing spring (D) restores the armature to its original position the moment the current ceases.

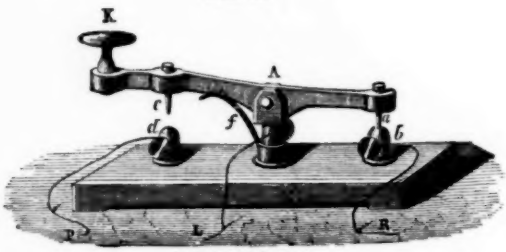
FIG. 10.



MORSE'S TELEGRAPH—MODIFIED FORM.

Morse's key (Fig. 11) is simply a brass lever, mounted on a hinge at A, and pressed up by the spring *f*. When the operator puts down the key, by pressing on the button (K) with his finger, the projections

FIG. 11.



MORSE'S KEY.

(*c d*) are brought into contact, and a current passes from the battery-wire (P) to the line-wire (L). When the key is up, the projections (*a b*) are in contact, and currents arriving by the line-wire pass by the wire R to the indicator or the relay. By keeping the key down for a longer

or shorter time, a dash or a dot is produced at the station to which the signal is sent. The dash and dot are combined in different ways to indicate the different letters, as shown in the following scheme, which is now generally adopted both in Europe and America:

MORSE'S ALPHABET.

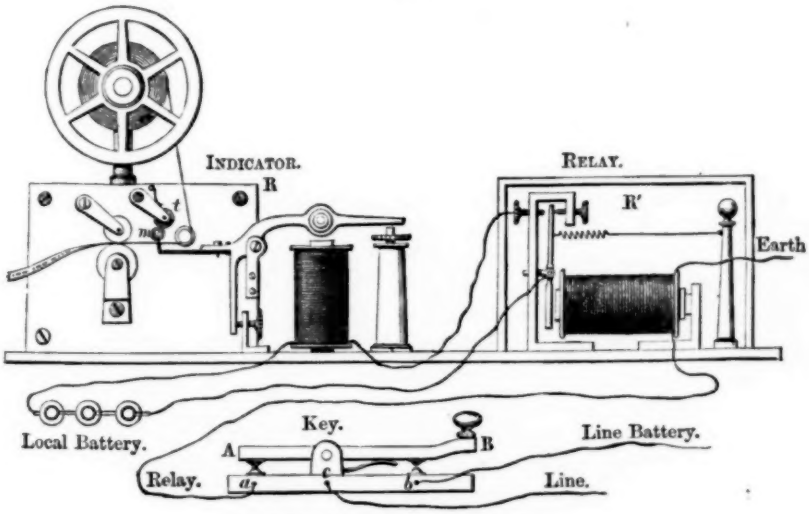
A · —	J · — — —	T —	1 · — — — —
Ä · — · —	K — · —	U · · —	2 · · — — · ·
B — · · ·	L · — · ·	Ü · · — —	3 · · · — —
C — · — ·	M — —	V · · · —	4 · · · · —
D — · ·	N — ·	W · — —	5 · · · · ·
E ·	O — — —	X — · · —	6 — · · · ·
É · · — · ·	Ö — — — ·	Y — · — —	7 — — · · ·
F · · — ·	P · — — ·	Z — — · ·	8 — — — · ·
G — — ·	Q — — · —	Ch — — — —	9 — — — — ·
H · · · ·	R · — ·		0 — — — — —
I · ·	S · · ·	Understood · · · — ·	

A space about equal to the length of a dash is left between two letters, and a space of about twice this length between two words.

In needle-telegraphs, the dot is represented by a deflection to the left, and the dash by a deflection to the right.

Fig. 12 represents Morse's indicator in connection with what is

FIG. 12.



MORSE'S APPARATUS, WITH RELAY.

called a *relay;* that is to say, an apparatus which, on receiving a feeble current from a distance, sends on a much stronger current from a battery on the spot. The key (B) being up, a current arriving by the line-wire passes through the key from *c* to *a*, thence through another

wire to the coil of the electro-magnet belonging to the relay, and through this coil to earth. The electro-magnet of the relay attracts an armature, the contact of which with the magnet completes the circuit of the local battery, in which circuit the coil belonging to the indicator is included. The armature of the indicator is thus compelled to follow the movements of the armature of the relay.

Relays are used when the currents which arrive are too much enfeebled to give clear indications by direct action. They are also frequently introduced at intermediate points in long lines which could not otherwise be worked through from end to end. The analogy of this use to change of horses on a long journey is the origin of the name. Relays are also frequently used in connection with alarums when these are large and powerful.

The employment of Morse's alphabet requires on the average about three currents to be sent per letter. The extension of telegraphic service has stimulated the industry of inventors to devise means for obtaining more rapid transmission. Hughes, about 1859, invented a system which requires only one current to be sent for each letter, and which, accordingly, sends messages in about a third of the time required by Morse's method. Hughes's machine also prints its messages in Roman characters on a strip of paper. These advantages are, however, obtained at the expense of extreme complexity in the apparatus employed. It is only fit for the use of skilled hands; but it is extensively employed on important lines of telegraph. We will proceed to indicate the fundamental arrangements of this marvellous piece of ingenuity.

Fig. 13 is a general view of the machine. It is propelled by powerful clock-work, with a driving weight of about 120 lbs., and with a regulator consisting of a vibrating spring (*l*) acting upon a 'scape-wheel. A travelling weight on the spring can be moved toward either end to regulate the quickness of the vibrations. The clock-work drives three shafts or axes: 1. The type-shaft, so called because it carries at its extremity the type-wheel (T), which has the letters of the alphabet engraved in relief on its circumference at equal distances, except that a blank space occurs at one place instead of a letter; 2. The printing-shaft, which turns much faster than the type-shaft, making sometimes 700 revolutions per minute, and carrying the fly-wheel (V). These two axes are horizontal, and are separately represented in Fig. 14; 3. A vertical shaft (*a*) having the same velocity as the type-wheel, which drives it by means of bevel-wheels.

This vertical shaft consists of two metallic portions, insulated from each other by an ivory connecting-piece. In the position represented in Fig. 14, these two metallic parts are electrically connected by means of the screw (V), but they will be disconnected by raising the movable piece (*v*).

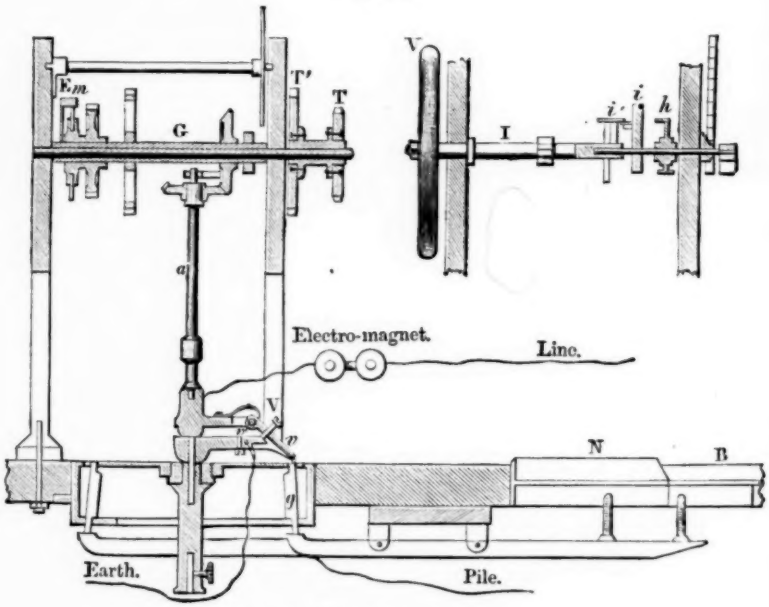
The revolving arm composed of the pieces *v' v* is called the *chariot.*

Fig. 13.

Hughes's Printing Telegraph.

It revolves with the vertical shaft, and travels over a disk (D) pierced with as many holes as there are letters on the type-wheel, these holes being ranged in a circle round the base of the shaft, and at such a distance from the shaft that the extremity of the chariot passes exactly over them. In these holes are the upper ends of a set of pins (g), which are raised by putting down a set of keys (B N) resembling those of a piano. When the chariot passes over a pin which is thus raised, the piece v is lifted away from v', and the current from the battery, which previously passed from the pin through v and v' to the earth, is now cut off from v', and passes through v to the electro-magnet, and thence to the line-wire.

FIG. 14.



TYPE-SHAFT AND PRINTING-SHAFT.

This is the process for sending signals. We will now explain how a current thus sent causes a letter to be printed by the type-wheels at both the sending and receiving stations, the sending and receiving instruments being precisely alike.

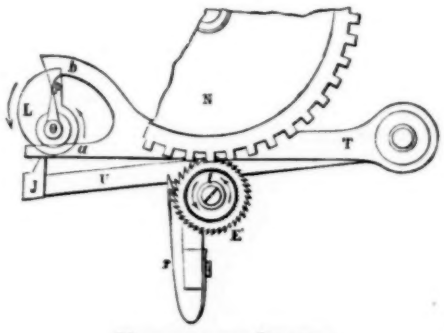
The current traverses the coils of an electro-magnet (E, Fig. 13), beneath which is a permanent steel horseshoe magnet, having its poles in contact with the soft-iron cores of the electro-magnet. When no current is passing, the influence of the steel renders these cores temporary magnets, and enables them to hold the movable armature (p) against the force of an opposing spring. The current is in such a direction that it tends to reverse the magnetism induced by the steel. It is not necessary, however, that it should be strong enough to pro-

duce an actual reversal, but merely that it should weaken the induced magnetism of the cores sufficiently to enable the opposing spring to overpower them. This is one of the most original parts of Hughes's apparatus, and is a main cause of its extreme sensibility.

The printing-shaft consists of two portions, one of which (I, Fig. 14) carries the fly-wheel (V), and turns uniformly under the action of the clock-movement; the other, which is next the front of the machine, remains at rest when no current is passing; but, when the armature of the magnet rises, the two parts of the shaft become locked together by means of the ratchet-wheel and click (*i i'*).

The portion of the shaft which is thus turned every time a current passes, carries a very acute cam or tooth (*p*, Fig. 15), which suddenly raises the lever (*a b*), movable about an axis at one end (T), and, by so doing, raises the paper against the type-wheel, and prints the letter. In order thus to print a letter from the rim of a wheel which continues turning, very rapid movement is necessary. This is secured by making the opposing spring which moves the armature very powerful, and the cam (*p*) very acute. The same movement of the lever which produces

Fig. 15.



Mechanism for Printing.

the impression, raises the arm (J U), which carries a spring (*r*) with a click at its extremity. This click, in its ascent, glides over the teeth of the ratchet-wheel (E), but locks into the teeth and turns the wheel in its descent, and, by so doing, advances the paper through the distance corresponding to one letter. The spacing of the words is obtained by the help of the blank on the type-wheel.

The type-wheel should admit of easy adjustment to restore it to agreement with the chariot when accidental derangement may have occurred. For this purpose the shaft (G) is made hollow, its internal and external portions being merely locked together by the click (*m*), which is held in its place by a permanent current in either direction. On pressing down the button (Q, Fig. 13), the click (*m*) is raised by the piece E, so as to leave the type-wheel free, and a pin is provided which

catches in a notch corresponding to the blank on the type-wheel. The adjustment can also be made by hand.

Lastly, the shaft (I) carries a third cam, which, at each revolution of this axis, engages with a very coarse-toothed wheel (T'), set on the same axis as the type-wheel, and pushes it a little forward or backward without detaching it from the driving-gear. Small discrepancies between the velocities of the type-wheel and chariot are thus corrected as often as a letter is printed. This contrivance serves to keep the receiving instrument from gaining or losing on the sending instrument during the transmission of a message. The type-wheel of the receiving instrument must be adjusted before the message begins, so as to make the two instruments start at the same letter.

Suppose a metallic cylinder, permanently connected with the earth, to be revolving, carrying with it on its surface a strip of paper freshly impregnated with cyanide of potassium. Also suppose a very light steel point permanently connected with the line-wire, and resting in contact with the paper. Every time that a current arrives by the line-wire, chemical action will take place at the point of contact, and the paper at this point will be discolored by the formation of Prussian blue. This is the principle of Bain's electro-chemical telegraph, which leaves a record in the shape of dots and dashes of Prussian blue. The apparatus for sending signals is the same as in Morse's system. The paper must not be too wet, or the record will be blurred; neither must it be too dry, for then no record will be obtained.

An autographic telegraph is one which produces at the receiving station a fac-simile of the original dispatch. The best known-instruments of this class are those of Bonelli and Caselli. We shall describe the latter.

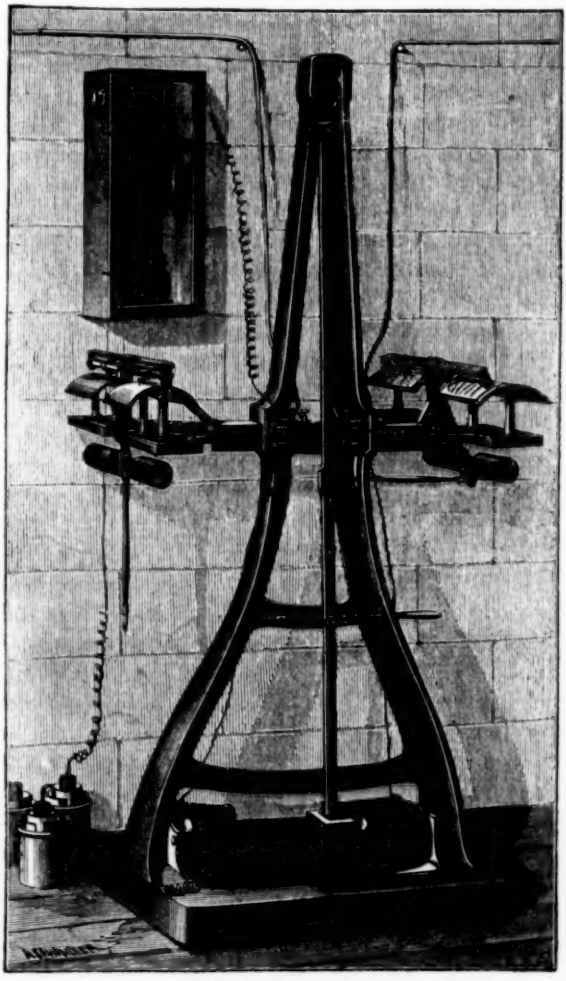
FIG. 16.

PRINCIPLE OF CASELLI'S TELEGRAPH

At the sending station a sheet of metallized paper, with the dispatch written upon it in a greasy kind of ink, is laid upon a cylindric surface (M, Fig. 16). At the receiving station there is a similar cylindric surface (R), on which a sheet of Bain's chemical paper is laid. Two styles, driven by pendulums which oscillate with exact synchronism, move over the surfaces of the two sheets, describing upon

them very close parallel lines at a uniform distance apart, both styles being in permanent connection with the line-wire. The current is furnished by the battery (P) at the sending station. When the style is on a conducting portion of the paper M, the current takes the course of least resistance (A B C D), no sensible portion of it going to the other station. On the other hand, when the style is on the non-conducting

FIG. 17.



CASELLI'S TELEGRAPH.

ink in which the dispatch is written, the circuit A B C D is broken, and the current travels through the line-wire. At this moment the style on the sheet R is in exactly the same position as that on the sheet M, by reason of the synchronism of the pendulums, and a blue line will

be produced which will be the exact reproduction of the broken line of the dispatch traversed by the style. Accordingly, when the style of M has described a series of lines close together and covering the sheet, R will be covered with a series of points or lines forming a copy of the dispatch. The tracing point is carried by a lever turning about an axis near its lower end. To this lower end is attached a connecting rod, jointed at its other end to the pendulum (Fig. 17). While the pendulum swings in one direction, the style traces a line in one direction on the sheet. At the end of this stroke, an action occurs which, besides advancing the style, raises it, so that it does not touch the sheet during the return-stroke.

The synchronism of the pendulums at the two stations, which is absolutely necessary for correct working, is obtained by means of two clocks which are separately regulated to a given rate, the clock-pendulums making two vibrations for one of the telegraphic pendulum. The bob of the latter consists of a mass of iron, and vibrates between two electro-magnets, which are made and unmade according to the position of the clock-pendulum, as the latter makes and breaks the circuit of a local battery. The mass of iron is thus alternately attracted by each of the two magnets as it comes near them, and is prevented from gaining or losing on the clock.

FIG. 18.

FAC-SIMILE OF DISPATCH.

FIG. 19.

COPY ON TIN-FOIL.

It is evident that the Caselli telegraph may be applied to copy not only letters, but a design of any kind; hence the name of *pantelegraph* which has been given it. Fig. 18 represents a copy thus obtained upon Bain's paper. Fig. 19 represents a copy obtained at the same time upon a sheet of tin-foil, such as is usually placed beneath the paper. The current decomposes the moisture of the paper, and the hydrogen thus liberated reduces the oxide of tin, of which a small quantity is always present on the surface. If the foil be then treated with a mixture of nitric and pyrogallic acid, the traces are developed, and come out black.

The Caselli system has been used for some years on the telegraphs

around Havre and Lyons, but has not realized the hopes of its promoters, its dispatches being often illegible.

Instead of a series of parallel lines, the styles may be made to trace the successive convolutions of a fine helix, the two sheets being bent round two cylinders, which revolve in equal times, and also advance longitudinally.

THE STUDY OF SOCIOLOGY.

By HERBERT SPENCER.

XIII.—*Discipline.*

IN the foregoing eight chapters we have contemplated, under their several heads, those "Difficulties of the Social Science" which the chapter bearing that title indicated in a general way. After thus warning the student against the errors he is liable to fall into, partly because of the nature of the phenomena themselves and the conditions they are presented under, and partly because of his own nature as observer of them—which by both its original and its acquired characters causes twists of perception and judgment—it now remains to say something about the needful preliminary studies. I do not refer to studies furnishing the requisite data, but I refer to studies giving the requisite discipline. Right thinking in any matter depends very much on the *habit* of thought; and the habit of thought, partly natural, depends in part on the artificial influences to which the mind has been subjected.

As certainly as each person has peculiarities of bodily action that distinguish him from his fellows, so certainly has he peculiarities of mental action that give a character to his conceptions. There are tricks of thought as well as tricks of muscular movement. There are acquired mental aptitudes for seeing things under particular aspects, as there are acquired bodily aptitudes for going through evolutions after particular ways. And there are intellectual perversities produced by certain modes of treating the mind, as there are incurable awkwardnesses due to certain physical activities daily repeated.

A truth ever to be remembered is, that each kind of mental discipline, besides its direct effects on the faculties brought into play, has its indirect effects on the faculties left out of play; and when special benefit is gained by extreme special discipline, there is inevitably more or less general mischief entailed on the rest of the mind by the consequent want of discipline. That antagonism between body and brain which we see in those who, pushing brain-activity to an extreme, enfeeble their bodies, and those who, pushing bodily activity to an extreme, make their brains inert, is an antagonism which holds between

the parts of the body itself and the parts of the brain itself. The greater bulk and strength of the right arm resulting from its greater use, and the greater aptitude of the right hand, are instances in point; and that the relative incapacity of the left hand, involved by cultivating the capacity of the right hand, would become still more marked were the right hand to undertake all manipulation, is obvious. The like holds among the mental faculties. The fundamental antagonism between feeling and cognition, running down through all actions of the mind, from the conflicts between emotion and reason to the conflicts between sensation and perception, is the largest illustration. We meet with a kindred antagonism, among the actions of the intellect itself, between perceiving and reasoning. Men who have marked aptitudes for accumulating observations are rarely men given to generalizing; while men given to generalizing are commonly men who, mostly using the observations of others, observe for themselves less from love of particular facts than from desire to put such facts to use. We may even trace the antagonism within a narrower range, between general reasoning and special reasoning. One prone to far-reaching speculations rarely pursues to much purpose those investigations by which particular truths are reached; while the scientific specialist ordinarily has but little tendency to occupy himself with wide views.

No more is needed to make it clear that habits of thought result from particular kinds of mental activity, and that each man's habits of thought influence his judgment on any question brought before him. It will be obvious, too, that, in proportion as the question is involved and many-sided, the habit of thought must be a more important factor in determining the conclusion arrived at. Where the subject-matter is very simple, as a geometrical truth or a mechanical action, and has therefore not many different aspects, perversions of view consequent on intellectual attitude are comparatively few; but, where the subject-matter is complex and heterogeneous, and admits of being mentally seen in countless different ways, the intellectual attitude affects very greatly the form of the conception.

A fit habit of thought, then, is all-important in the study of Sociology; and a fit habit of thought can be acquired only by study of the Sciences at large. For Sociology is a science in which the phenomena of all other sciences are included. It presents those necessities of relation with which the Abstract Sciences deal; it presents those connections of cause and effect which the Abstract-Concrete Sciences familiarize the student with; and it presents that concurrence of many causes and production of contingent results which the Concrete Sciences show us, but which we are shown especially by the organic sciences. Hence, to acquire the habit of thought conducive to right thinking in Sociology, the mind must be familiarized with the fundamental ideas which each class of sciences brings into view, and must not be possessed by those of any one class, or any two classes, of sciences.

That this may be better seen, let me briefly indicate the indispensable discipline which each class of sciences gives to the intellect, and also the wrong intellectual habits produced if that class of sciences is studied exclusively.

Entire absence of training in the Abstract Sciences leaves the mind without due sense of *necessity of relation*. Watch the mental movements of the wholly ignorant, before whom not even the exact and certain results of Arithmetic have been frequently brought, and it will be seen that there exists nothing like irresistible conviction that from given data there is an inevitable inference. That which to you has the aspect of a necessity, seems to them not free from doubt. Even men whose educations have made numerical processes and results tolerably familiar, will show, in a case where the implication is logical only, that they have not absolute confidence in the dependence of conclusion on premisses.

Unshakable beliefs in necessities of relation, are to be gained only by studying the Abstract Sciences, Logic and Mathematics. Dealing with necessities of relation of the simplest class, Logic is of some service to this end; though often of less service than it might be, for the reason that the symbols it uses are not translated into thought, and the connections stated not really represented. Only when, for a logical implication expressed in the abstract, there is substituted an example so far concrete that the interdependencies can be contemplated, is there an exercise of the mental power by which logical necessity is grasped. Of the discipline given by Mathematics, also, it is to be remarked that the habit of dealing with the necessities of numerical relation, though in a degree useful for cultivating the consciousness of necessity, is not in a high degree useful; because, in the immense majority of cases, the mind, occupied with the symbols used, and not passing beyond them to the groups of units they stand for, does not really figure to itself the relations expressed,—does not really discern their necessities, and has not therefore the conception of necessity perpetually repeated. It is the more special division of Mathematics, dealing with Space-relations, which, above all other studies, yields necessary ideas, and so makes strong and definite the consciousness of necessity in general. A geometrical demonstration time after time presents premisses and conclusion in such wise that the relation alleged is seen in thought—cannot be passed over by mere symbolization. Each step exhibits some connection of positions or quantities as one that could not be otherwise; and hence the habit of taking such steps makes the consciousness of such connections familiar and vivid.

But, while mathematical discipline, and especially discipline in Geometry, is extremely useful, if not indispensable, as a means of preparing the mind to recognize throughout Nature the absoluteness

of uniformities, it is, if exclusively or too habitually pursued, apt to produce perversions of general thought. Inevitably it generates a special bent of mind; and inevitably this special bent affects all the intellectual actions—causes a tendency to look in a mathematical way at questions beyond the range of Mathematics. The mathematician is ever dealing with phenomena of which the elements are relatively few and definite. His most involved problem is immeasurably less involved than are the problems of the Concrete Sciences. But he cannot help bringing with him his mathematical habits of thought; and, in dealing with questions which the Concrete Sciences present, he recognizes some few only of the factors, tacitly ascribes to these a definiteness which they have not, and proceeds after the mathematical manner to draw positive conclusions from these data, as though they were specific and adequate.

Hence the truth, so often illustrated, that mathematicians are bad reasoners on contingent matters. To previous illustrations may be added the recent one yielded by M. Michel Chasles, who proved himself incapable as a judge of evidence in the matter of the Newton-Pascal forgeries. Another was supplied by the late Prof. De Morgan, who, bringing his mental eye to bear with microscopic power on some small part of a question, ignored its main features.

By cultivation of the Abstract-Concrete Sciences, there is produced a further habit of thought, not otherwise produced, which is essential to right thinking in general, and by implication to right thinking in Sociology. Familiarity with the various orders of physical and chemical phenomena gives distinctness and strength to the consciousness of *cause and effect*.

Experiences of things around do, indeed, yield conceptions of special forces and of force in general. The uncultured get from these experiences degrees of faith in causation such that, where they see some striking effect, they usually assume an adequate cause, and, where a cause of given amount is manifest, a proportionate effect is looked for. Especially is this so where the actions are simple mechanical actions. Still, these impressions which daily life furnishes, if unaided by those derived from physical science, leave the ordinary mind with but vague conceptions of causal relations. It needs but to remember the readiness with which people accept the alleged facts of the Spiritualists, many of which imply a direct negation of the mechanical axiom that action and reaction are equal and opposite, to see how much the ordinary thoughts of causation lack quantitativeness—lack the idea of proportion between amount of force expended and amount of change wrought. Very generally, too, the ordinary thoughts of causation are not even qualitatively valid; the most absurd notions as to what cause will produce what effect are frequently disclosed. Take, for instance, the popular belief that a goat kept in a stable will preserve the health of

the horses; and note how this belief, accepted on the authority of grooms and coachmen, is repeated by their educated employers—as I lately heard it repeated by an American general, and agreed in by two retired English officials. Clearly, the readiness to admit, on such evidence, that such a cause can produce such an effect, implies a consciousness of causation which, even qualitatively considered, is of the crudest kind. And such a consciousness is, indeed, everywhere betrayed by the superstitions prevalent more or less among all classes.

Hence we must infer that the uncompared and unanalyzed observations men make, in the course of their dealings with things around, do not suffice to give them wholly-rational ideas of the process of things. It requires that physical actions shall be critically examined, the factors and results measured, and different cases contrasted, before there can be reached clear ideas of necessary causal dependence. And thus to investigate physical actions is the business of the Abstract-Concrete Sciences. Every experiment which the physicist or the chemist makes brings afresh before his consciousness the truth, given countless times in his previous experiences, that from certain antecedents of particular kinds there will inevitably follow a particular kind of consequent; and that, from certain amounts of the antecedents, the amount of the consequent will be inevitably so much. The habit of thought generated by these hourly-repeated experiences, always the same, always exact, is one which makes it impossible to think of any effect as arising without a cause, or any cause as expended without an effect; and one which makes it impossible to think of an effect out of proportion to its cause, or a cause out of proportion to its effect.

While, however, study of the Abstract-Concrete Sciences, carried on experimentally, gives clearness and strength to the consciousness of causation, taken alone it is inadequate as a discipline; and, when pursued exclusively, generates a habit of thought which betrays into erroneous conclusions when higher orders of phenomena are dealt with. The process of physical inquiry is essentially analytical; and the daily pursuit of this process generates two tendencies—the tendency to contemplate separately the factors of phenomena, which it is the aim of inquiry to disentangle, and identify, and measure, and the tendency to rest in the results of such inquiry as though they were the final results to be sought. The chemist, by saturating, neutralizing, decomposing, precipitating, and at last separating, is enabled to measure what quantity of this element had been held in combination by a given quantity of that; and, when, by some alternative course of analysis, he has verified the result, his inquiry in so far is concluded: as are kindred inquiries respecting the other affinities of the element, when they are qualitatively and quantitatively determined in like ways. His habit is to get rid of, or neglect as much as possible, the concomitant disturbing factors, and to ascertain the nature and amount of some one and then of some other; and his end is reached when accounts have been

given of all the factors individually considered. So is it, too, with the physicist. Say the problem is the propagation of sound through air, and the interpretation of its velocity—say that the velocity as calculated by Newton is found less by one-sixth than observation gives, and that Laplace sets himself to explain the anomaly. He recognizes the evolution of heat by the compression which each sound-wave produces in the air; finds the extra velocity consequent on this; adds this to the velocity previously calculated; finds the result answer to the observed fact; and then, having analyzed the phenomenon into its components and measured them, considers his task concluded. So throughout: the habit is that of identifying, parting, and estimating factors, and stopping after having done this completely.

This habit, carried into the interpretation of things at large, affects it somewhat as the mathematical habit affects it. It tends toward the formation of unduly-simple and unduly-definite conceptions; and it encourages the natural propensity to stop short with proximate results. The daily practice of dealing with single factors of phenomena, and with factors complicated by but few others, and with factors ideally separated from their combinations, inevitably gives to the thoughts about surrounding things an analytic rather than a synthetic character. It promotes the contemplation of simple causes apart from the entangled *plexus* of coöperating causes which all the higher natural phenomena show us, and begets a tendency to suppose that, when the results of such simple causes have been exactly determined, nothing remains to be sought.

Physical science, then, though indispensable as a means of developing the consciousness of causation in its simple definite forms, and thus preparing the mind for dealing with complex causation, is not sufficient of itself to make complex causation truly comprehensible. In illustration of its inadequacy, I might name a distinguished mathematician and physicist whose achievements place him in the first rank, but who, nevertheless, when entering on questions of concrete science, where the data are no longer few and exact, has repeatedly shown defective judgment. Choosing premisses which, to say the least, were gratuitous and in some cases improbable, he has proceeded by exact methods to draw definite conclusions, and has then enunciated those conclusions as though they had a certainty proportionate to the exactness of his methods.

The kind of discipline which affords the needful corrective is the discipline which the Concrete Sciences give. Study of the *forms* of phenomena, as in Logic and Mathematics, is needful, but by no means sufficient. Study of the *factors* of phenomena, as in Mechanics, Physics, Chemistry, is also essential, but not enough by itself, or enough even joined with study of the forms. Study of the *products* themselves, in their totalities, is no less necessary. Exclusive attention to forms and factors will not only fail to give right conceptions of prod-

ucts, but will even tend to make the conceptions of products wrong. The analytical habit of mind has to be supplemented by the synthetical habit of mind. Seen in its proper place, analysis has for its chief function to prepare the way for synthesis; and, to keep a due mental balance, there must be not only a recognition of the truth that synthesis is the end to which analysis is the means, but there must also be a practice of synthesis along with a practice of analysis.

All the Concrete Sciences familiarize the mind with certain cardinal conceptions which the Abstract and Abstract-Concrete Sciences do not yield—the conceptions of *continuity*, *complexity*, and *contingency*. The simplest of the Concrete Sciences, Astronomy and Geology, yield the idea of continuity with great distinctness. I do not mean continuity of existence merely; I mean continuity of causation: the unceasing production of effect—the never-ending work of every force. On the mind of the astronomer there is vividly impressed the idea that any one planet which has been by so much swerved out of its course by another planet, or by a combination of others, will through all future time follow a route different from that it would have followed but for the perturbation; and he recognizes its reaction upon the perturbing planet or planets, as similarly having effects which, while ever being complicated and ever slowly diffused, will never be lost during the immeasurable periods to come. So, too, the geologist sees in each change wrought on the earth's crust, by igneous or aqueous action, a new factor that goes on perpetually modifying all subsequent changes. An upheaved portion of sea-bottom alters the courses of ocean-currents, modifies the climates of adjacent lands, affects their rainfalls and prevailing winds, their denudations and the deposits round their coasts, their floras and faunas; and these effects severally become causes that act unceasingly in ever-multiplying ways. Always there is traceable the persistent working of each force, and the progressive complication of the results through succeeding geologic epochs.

These conceptions, not yielded at all by the Abstract and Abstract-Concrete Sciences, and yielded by the inorganic Concrete Sciences in ways which, though unquestionable, do not arrest attention, are yielded in clear and striking ways by the organic Concrete Sciences—the sciences that deal with living things. Every organism, if we choose to read the lessons it gives us, shows continuity of causation and complexity of causation. The ordinary facts of inheritance illustrate continuity of causation—very conspicuously where varieties so distinct as negro and white are united, and where traces of the negro come out generation after generation; and still better among domestic animals, where traits of remote ancestry show the persistent working of causes which date far back. Organic phenomena make us familiar with complexity of causation, both by showing the coöperation of many antecedents to each consequent, and by showing the multiplicity of results which each influence works out. If we observe how a given weight

of a given drug produces on no two persons exactly like sets of effects, and produces even on the same person different effects in different constitutional states, we see at once how involved is the combination of factors by which the changes in an organism are brought about, and how extremely contingent, therefore, is each particular change. And we need but watch what happens after an injury, say of the foot, to perceive how, if permanent, it alters the gait, alters the adjustment and bend of the body, alters the movements of the arms, alters the features into some contracted form accompanying pain or inconvenience. Indeed, through the readjustments, muscular, nervous, and visceral, which it entails, this local damage acts and reacts on function and structure throughout the whole body, producing effects which, as they diffuse, complicate incalculably.

While, in multitudinous ways, the Science of Life thrusts on the attention of the student the cardinal notions of continuity, and complexity, and contingency, of causation, it introduces him to a further conception of moment, which the inorganic Concrete Sciences do not furnish—the conception of what we may call *fructifying* causation. For, as it is a distinction between living and not-living bodies that the first propagate while the second do not, it is also a distinction between them that certain actions which go on in the first are cumulative, instead of being, as in the second, dissipative. Not only do organisms as wholes reproduce, and so from small beginnings are capable, by multiplication, of reaching great results; but components of them, normal and morbid, do the like. Thus a minute portion of a virus, introduced into an organism, does not work an effect proportionate to its amount, as would an inorganic agent on an inorganic mass; but, by appropriating materials from the blood of the organism, and thus immensely increasing, it works effects altogether out of proportion to its amount as originally introduced—effects which may continue with accumulating power throughout the remaining life of the organism. It is so with internally-evolved agencies as well as with externally-invading agencies. A portion of germinal matter, itself microscopic, may convey from a parent some constitutional peculiarity that is infinitesimal in relation even to its minute bulk; and from this there may arise, fifty years afterward, gout or insanity in the resulting man: after this great lapse of time, slowly-increasing actions and products show themselves in large derangements of function and structure. And this is a trait characteristic of organic phenomena. While, from the *destructive* changes going on throughout the tissues of living bodies, there is a continual production of effects which lose themselves by subdivision, as do the effects of inorganic forces, there arise from those *constructive* changes going on in them, by which living bodies are distinguished from not-living bodies, certain classes of effects which increase as they diffuse—go on augmenting in volume as well as in variety.

Thus, as a discipline, study of the Science of Life is essential; partly as familiarizing the mind with the cardinal ideas of continuity, complexity, and contingency, of causation in clearer and more various ways than do the other Concrete Sciences, and partly as familiarizing the mind with the cardinal idea of fructifying causation, which the other Concrete Sciences do not present at all. Not that, pursued exclusively, the Organic Sciences will yield these conceptions in clear forms: there requires a familiarity with the Abstract-Concrete Sciences to give the requisite grasp of simple causation. Studied by themselves the Organic Sciences tend rather to make the ideas of causation cloudy; for the reason that the entanglement of the factors and the contingency of the results is so great that definite relations of antecedents and consequents cannot be established: the two are not presented in such connections as to make the conception of causal action, qualitative and quantitative, sufficiently distinct. There requires, first, the discipline yielded by Physics and Chemistry, to make definite the ideas of forces and actions as necessarily related in their kinds and amounts; and then the study of organic phenomena may be carried on with a clear consciousness that while the processes of causation are so involved as often to be inexplicable, yet there *is* causation, no less necessary and no less exact than causation of simpler kinds.

And now to apply these considerations on mental discipline to our immediate topic. For the effectual study of Sociology there needs a habit of thought generated by the studies of all these sciences; since, as already said, social phenomena involve phenomena of every order.

That there are necessities of relation such as those with which the Abstract Sciences deal, cannot be denied, when it is seen that societies present facts of number and quantity. That the actions of men in society, in all their movements and productive processes, must conform to the laws of the physical forces, is also indisputable. And that every thing thought and felt and done in the course of social life is thought and felt and done in harmony with the laws of individual life, is also a truth—almost a truism, indeed; though one of which few seem conscious.

Culture of the sciences in general, then, is needful; and, above all, culture of the Science of Life. This is more especially requisite, however, because the conceptions of continuity, complexity, and contingency, of causation, as well as the conception of fructifying causation, are conceptions common to it and to the Science of Society. It affords a specially-fit discipline, for the reason that it alone among the sciences produces familiarity with these cardinal ideas—presents the data for them in forms easily grasped, and so prepares the mind for recognizing the data for them in the Social Science, where they are less easily grasped, though no less constantly presented.

The supreme importance of this last kind of culture, however, is

not to be adequately shown by this brief statement. For, besides generating habits of thought appropriate to the study of the Social Science, it furnishes the mind with special conceptions which serve as keys to the Social Science. The Science of Life yields to the Science of Society certain great generalizations without which there can be no Science of Society at all. Let us go on to observe the relations of the two.

FOOTPRINTS IN THE ROCKS.

By CHARLES H. HITCHCOCK, A. M.,
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SEVENTY years ago, a student belonging to Williams College, while holding the plough in his father's field at South Hadley, Massachusetts, turned over a flat slab of sandstone about three feet long. His attention was directed to what seemed to be a row of bird-tracks upon its surface. He had often noticed—as has every intelligent person—the impressions made by the feet of animals in the mud, upon the shores of rivers, lakes, and in the highway. But he had never before seen the imprint of an animal's foot upon the solid rock, and had been taught to believe that the ledges were suddenly called into being by the Almighty without passing through a tedious formative process. Here, however, was a phenomenon not to be explained in accordance with the popular opinion—real footprints in the solid rock—and how came they there?

It was before the days of much geological knowledge, but Pliny Moody exercised a common-sense method of explaining what he saw; for he concluded that these markings were made by some animal in an early period of the earth's history. Nothing was more natural to him than to surmise that they were made during the earliest aqueous deposit of which he had heard—the muddy sediments left by the Noachian Deluge. Hence he pointed out these foot-marks to his friends—the specimen being utilized for a stepping-stone at his front-door—as having been made by Noah's raven when wandering in search of dry land. The slab is still preserved, and the impressions appear to have been made by one of that remarkable group of animals which abounded in New England during the Triassic or New Red Sandstone period.

Thirty-five years later, as Mr. W. W. Draper, of Greenfield, a village thirty miles farther north, was returning home from church, his attention was arrested by the sliding of snow from some large paving-stones leaning against a fence. As he turned his eyes, he saw a row of apparent ornithic impressions on the slab, shown very distinctly on account of the reflection of the sun's rays from a wet surface. A

philosophic induction was the result of his observation, and he immediately remarked to his wife: "There are some turkey's tracks made three thousand years ago!"

These two minds, though untutored in scientific lore, each independently of the other, expressed that fundamental generalization of paleontology which has never been set aside, though wondrously amplified and illustrated since that time: that these impressions were made by living animals in immensely remote periods, when the physical geography of the country differed from what it is at present—that is to say, when the existing solid ledges were in the formative process.

Mr. Draper soon communicated his views to his friends, especially to Captain John Wilson. Captain Wilson did the same to Dexter Marsh, and Mr. Marsh to the village physician, Dr. James Deane. All these gentlemen coincided with the theory of Mr. Draper, that the markings were turkey-tracks; but, as none of them were geologists, they felt the need of competent advice. Accordingly, Dr. Deane sent descriptions of the slabs to the State Geologist, the late Prof. Edward Hitchcock, of Amherst, urging him to come and examine them. A similar sketch was sent to the late Prof. Benjamin Silliman, of New Haven, who expressed no opinion about it, but wished Prof. Hitchcock to investigate the subject. As soon as it was convenient, this gentleman went to Greenfield and examined the specimens. His acquaintance with geological literature and methods of investigation apprised him that this new theory, though plausible, must pass through a severe ordeal before it could be established. Not merely was it questionable whether footprints could be preserved for ages, but it was a monstrous assumption—unheard of in geological circles—to talk of birds as a part of the Triassic fauna! Such an announcement could not fail to evolve unanimous disapproval; and, if premature, if published without careful investigation, it might prove to be an egregious blunder, and haunt the unfortunate author through his lifetime.

The scientific investigation of the subject having been thus urgently placed in Prof. Hitchcock's hands by those immediately and remotely interested, he spent the summer of 1835 in studying the characters derived from the progression of animals, whether birds or quadrupeds. Visits were made to all the sandstone-quarries in the Connecticut Valley, to menageries, museums, and libraries, thus insuring the inspection of all slabs exhibiting similar impressions, an examination of the feet of living animals, especially of those most nearly allied to the new forms, and the assurance that nothing similar had ever been found in any part of the world. The result of this protracted investigation indicated the truth of the first surmises—that these impressions were actually made by the feet of birds in the Triassic period. A full account of the discoveries was published in Prof. Silliman's magazine, the *American Journal of Science and Art* for January, 1836. Descriptions were given of seven species of avian im-

pressions, called *Ornithichnites*, or *bird-tracks on stone*. One of them was a foot of gigantic dimensions, not less than sixteen inches long, three times larger than its nearest living representative. It was no wonder that, in these early days, even the father of the science hesitated to admit these monsters into his ichnitic family, yet so exact are the laws of comparative anatomy, and so like the rows of impressions made by living feet were these giants, that a relationship to existing groups could be no longer denied.

A few geologists accepted these doctrines immediately after their promulgation; but most of them, as well as the community in general, doubted whether the preservation of foot-marks were possible, and especially whether they could have been made by birds. Some thought the resemblance was fanciful; others that they were the remains of peculiar marine plants. The public mind, which had no scientific appreciation of the subject, saw abundant opportunity for witticism, and did not spare the shaft of ridicule. The American Association of Geologists and Naturalists at length appointed a committee to investigate the subject, including in the list both the friends and opponents of the new views. They visited Prof. Hitchcock in due time, explored the quarries, examined his specimens, and became convinced unanimously that his views were correct. Their report to the Association states that "the evidence entirely favors the views of Prof. Hitchcock, and they regret that a difference had existed, if they did not feel assured it would lead to greater stability of opinion." This committee consisted of H. D. Rogers, E. Emmons, Lardner Vanuxem, Richard C. Taylor, and T. A. Conrad.

The public generally acquiesced in the truth of this report; they ceased to ridicule, and began to believe that a new chapter in the earth's history had been laid bare for perusal; great popular interest was excited in the foot-marks, and at the present day everybody has heard of the wonderful tracks upon stone in the Connecticut River Valley. The name of their principal expounder, who first published an account of them to the world, and waged a seven years' contest with his compeers and the public on this account, has become indelibly associated with them.

The results of Prof. Hitchcock's researches have been published in two large quarto volumes entitled "The Ichnology of New England." Of other publications, the "Ichnographs" of the Connecticut sandstone are worthy of notice as a monument to the memory of Dr. James Deane, whose early interest in the foot-marks never flagged, and who applied himself earnestly to the study of geology, so that his later writings have become invested with the authority of an able and accurate observer.

Amherst College now possesses the unrivalled collection of ichnites collected by Prof. Hitchcock. They occupy a room 100 feet long and 40 feet wide, and are more than 20,000 in number.

The first scientific publication concerning fossil foot-marks is contained in the Transactions of the Royal Society of Edinburgh in 1828. Six years later, Prof. Kaup described the tracks of the *Cheirotherium, a beast with hands*, upon Triassic sandstones in Germany. The animal must have equalled an ox in size, with hind-feet shaped like the human hand, which were about three times larger than the front-feet. He is generally supposed to have been a batrachian. The earliest description of the American ichnites appeared in 1836.

The Triassic formations on the Atlantic slope are disposed in long and narrow areas. These may correspond with the spaces occupied by estuaries before the deposition of the strata. We may suppose that an arm of the sea extended northerly from Long Island Sound to New Hampshire along the Connecticut Valley, possibly connecting, beneath the Sound and North River, with a similar estuary running southerly to Virginia. If we transport ourselves in imagination to these ancient shores, we shall see that the animals left their hiding-places and were traversing the soft mud laid bare by the ebbing tide, in search of food. The heat of a tropical sun quickly hardens the mud, so that the returning tide, in bringing a fresh deposit of mud, does not wash away the impressions already made on the lower layer, but carefully covers them over. The imprints have, therefore, become a species of mould into which another muddy fluid is poured, and by hardening is made to copy the foot-mark like a plaster cast. Hence, when artificially cleared, no matter how many ages subsequently, the strata will present to view the depressed print below and the cast of the foot above, both as perfect as the respective fineness of the mud and its degree of rapid induration by the sun will permit. This process of deposition may have been repeated, just as it may now be studied, in the Bay of Fundy, till the whole estuary was filled up, partly with fine mud and clay, partly with beds of sand and gravel, all more or less marked by the feet of animals, interspersed with volcanic beds of lava, tufa, and conglomerate, and rare chemical deposits of carbonate of lime, salt, and gypsum.

The *Ichnozoa*, or the animals who made the tracks on stones in Triassic times, may be referred to several prominent divisions of the animal kingdom. The first, and highest in the scale, is a group of five species, remotely allied to marsupials, which, from their osseous remains found in Europe, we know must have flourished in that period. The most characteristic is a five-toed quadruped, about the size of a lion, whose foot is not unlike that of a carnivorous animal. The others had unequal feet, larger behind and smaller in front. The most important groups are those referred to birds, embracing thirty-four species; equally divided between those related to the ostrich family—thick-toed—and those with long, slender toes, like the crane and heron. These are the impressions chiefly relied upon to prove the ornithic character of any of the Ichnozoa, as they show distinctly the phalangeal

joints of the toes, like the tracks of the ostrich, turkey, and our common domestic fowls. The feet are invariably trifid, and the number of phalanges corresponds perfectly to that observed in the toes of all living birds, viz., three in the inner, four in the middle, and five in the outer toe, including the claws. The inner phalanges are united to the lower leg-bone abreast of each other, a little back of the middle one, and thus the imprint may also show rounded impressions made by the heel, which have been mistaken for phalangeal markings. This thick-toed group invariably took very long steps, corresponding well with the ordinary gait of their living representatives. One of them, with a foot less than three inches long, had a stride of 25 inches, showing a general structure like that of the waders. Moreover, the entire width of the track-way is scarcely greater than that of each individual foot, indicating a very narrow body, stilted high upon long legs. The smallest of this group may be compared with the living snipe; the largest, having a foot 18 inches long, must have equalled in size the largest of the recently-extinct birds of New Zealand, the *Deinornis giganteus*, 10 feet high. The principal genus is the *Brontozoum* (*the animal giant*); and of the thousands of examples of those yet exhumed, not one shows any features in addition to those described, neither a fourth toe, the trace of a front-foot, nor any indication of a tail. Hence, though suggestions as to their reptilian character are abundant, we shall wait for proof that some distinct reptilian feature is joined to the ornithic, before allowing that the *Brontozoum*, or *Grallator*, were not true birds.

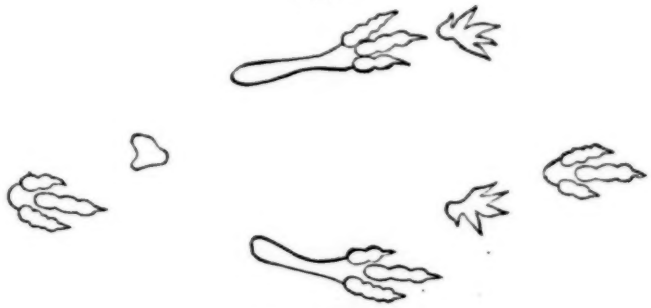
But the next group gives evidences, neither scanty nor ambiguous, to prove the existence of a large number of "ornithic reptiles," or "reptilian birds." This order is now entirely extinct, and was first made known to the world by E. Hitchcock's description of the "ornithoid lizards, or batrachians." He saw that some of the characters were ornithic, and that others were reptilian, so that he was compelled, though reluctantly, to refer them to an altogether new group of life. Since this reference, an abundance of discoveries has confirmed these views; and the name of *Herpetoids* has been suggested for them by Prof. Dana.*

The general form of the animal was kangaroo-like, with enormous hind-limbs, a prominent tail, and small front extremities, which were rarely if ever brought to the ground so as to make an impression. The animal may often have walked only upon the trifid hind-feet, showing neither the front-feet, the long shin-bones, nor the caudal appendage. We have seen such rows of trifid impressions, 25 or 30 in number, which might hastily be referred to the feet of birds. But, though the general appearance is ornithic, and the number of phalanges agrees with those of birds, the thirty-first impression reveals a kangaroo-form on all-fours—two small five-toed feet in front, two trifid impressions of larger dimensions at the end of a long heel-mark behind, followed

by a heart-shaped print, or a trail, that has come from the caudal appendage. This remarkable quadrupedal display is succeeded by another row of trifid impressions; just as if the animal stopped to rest on his journey, and then resumed his line of march.

Surely no one can doubt the quadrupedal character of this *Anomœpus*. Yet, it was not till after years of discussion and discovery had

FIG. 1.



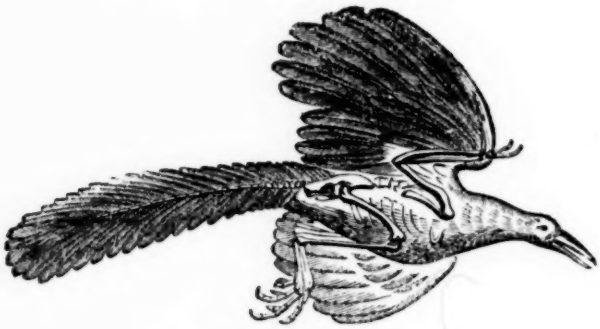
ANOMŒPUS MAJOR.

elapsed that his true relationship was appreciated. The first-discovered rows were supposed to be ornithic, and it was these quadrupedal features that led some authors hastily to infer that all the trifid impressions were reptilian, or marsupial. The bipedal rows themselves offer two features distinguishing the most nearly-allied forms from the birds: first, the animals took very short steps; and, secondly, the great width of the track-way indicated a very broad body, probably inferior, in delicacy of organization, to that of birds. To these two invariable characters are commonly added a caudal trail, a fourth toe on an occasional front-foot impression, so that the study of a large suite of specimens will satisfy the most truthful observer that these animals were not birds. The total number of species of this character is 21. One of these equalled the largest *Brontozoum* in size, whose front-foot has not yet been found, though we have indications of a fourth toe behind, and a long, slender tail.

It may not be out of place to allude briefly to the discoveries which have confirmed the existence of the group of ornithic reptiles. The first link in the series was furnished by the discovery of the nearly-complete skeleton of a bird related to the raven in the lithographic stone of the Jurassic series of Bavaria, called the *Archeopteryx*. A feather belonging to this genus was found in 1861, and described with great minuteness by Hermann von Meyer. Shortly afterward, Andreas Wagner described the nearly-complete skeleton of an animal, to which were attached feathers like the one made known by Von Meyer. He called the animal a flying reptile. Prof. Owen, of the British Museum, made a very thorough examination of the same specimen,

and perceived that the feathers corresponded with that named by Von Meyer. It seems to differ in only two particulars from ordinary birds: first, there are two fore-fingers, like hooks, projecting from the wings; and, secondly, the tail is shaped like that of the squirrel, with twenty vertebræ ranged in a line, each with a pair of quill-feathers attached. These variations are not sufficiently great to render it necessary to remove the *Archeopteryx* from the bird division, but they indicate in

FIG. 2.



ARCHEOPTERYX.

what direction we are to expect a modification of the ornithic type, as it approaches the reptile. And it is in precisely these two respects that the Triassic Herpetoids differ from true birds.

The second link was furnished by the structure of the feet and the ichnites of the *Iguanodon* in England. Both pairs of limbs were terminated by three-toed feet, often of great size. Only two impressions appear, yet Prof. Owen supposes the tracks of the fore-feet were always covered by the hind-feet. The largest of these impressions are 28 inches long and 25 broad, and the stride sometimes reaches 46 inches. This was the largest of all the English terrestrial herbivorous reptiles, and his impressions have been extensively collected near Hastings.

The third link was furnished by the *Hadrosaurus* of New Jersey, the American representative of the *Iguanodon*. He appears to have had the general form of the kangaroo, enormous hind-limbs, terminated by trifid feet; a powerful tail, almost rudimentary anterior extremities, with a skull slightly ornithic, the height of the structure being from 12 to 15 feet. It is singularly like the Ichnozoa *Gigantitherium*. In fact, if we may follow the fashionable creed of the day, it may be said that the New-Jersey *Hadrosaurus* was the lineal descendant of the Massachusetts *Gigantitherium*.

For other links of this series it is only necessary to refer to the late publications of Cope, Huxley, Seely, Owen, Marsh, and other distinguished paleontologists, in which are described nearly a score of

kangaroo-like reptiles flourishing, in the later Mesozoic times, in all quarters of the globe. All those new forms present features clearly defining them from both birds on the one hand, and reptiles on the other, so that we are warranted in believing in the existence of genuine birds as well as of ornithic reptiles in ichniferous times.

Fig. 3.

Gigantitherium.

The Triassic period was *par excellence* the Age of Reptiles. Besides the Ichnozoa, the museums teem with specimens of fossil bones of various types of Amphibian, Batrachian, Crocodilian, and Lacertilian forms. We should, therefore, naturally expect that a kangaroo-form of body was not indicative of marsupial structure, but rather a modification of reptilian, in the passage, if we may so speak, of the Lacertian to the Ornithic type.

Twenty-one of the Connecticut ichnites have been referred to the ordinary type of reptiles—the Lacertians—and six to the turtles. Perhaps the number of the former should be increased at the expense of the marsupials and narrow-toed birds. The largest reptile foot is about 15 inches long, three toes in front, curved toward the line of march. It has, besides, a stout thumb, or spur, pointed inwardly. The track-ways of turtles show the trail of the tail, in addition to a pair of feet on both sides.

The group of Amphibians, chiefly batrachians, contains several of interest. Prominent among them is the *Otozoum*, a track discovered by Mr. Pliny Moody, the first person in the whole world who exhumed an ichnite, so far as has been determined. The animal had a foot 20 inches long, very broad, perhaps web-footed, embracing not less than a square foot of surface. In shape it resembles the *Cheirotherium*, only it had three fingers instead of four, with a thumb. One species has the thumb recurved, and the other shows it pointed direct-

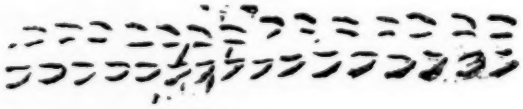
ly forward. The front is about one-third the size of this large hind-foot, and the toes are arranged like those of the front-feet of the Herpetoids. One of the species seems to have had a long, slender tail. This batrachian must have been as large as an elephant, and exceeded in size every other animal among the Ichnozoa. Imagine a frog as large as an elephant, whether announcing the advent of spring by piping, croaking at night in the summer, or taking gigantic leaps after the manner of his modern representatives!

A very important character in the feet of frogs is the possession of pellets, or knobs, instead of claws, at the ends of the toes. These may be observed in the *Otozoum*, and all the other genera of this group. One genus resembles the *Cheirotherium* in form, but not in size, having a foot less than an inch long. None have the remarkably long middle toes on the hind-foot, so characteristic of living frogs.

A small, living salamander has the posterior feet pointing backward; and, as he walks, the toes point away from the head. The track-way, therefore, consists of two parallel rows of footprints, half of each pointing forward and half directed backward. This salamander has its representative ichnozoan in the *Stenodactylus*, not varying essentially in size from it.

One of the most interesting classes of batrachian impressions is called *Batrachoides*. They consist of numerous saucer-shaped hollows an inch in diameter, crowded together so thickly that the original oval outlines have become pentagonal. Not unfrequently these saucers are arranged in lines and squares, because parallel rows of ripple-marks were occupied by the animals in their construction, often covering several square yards of surface.

FIG. 4.



BIFURCULIPES.

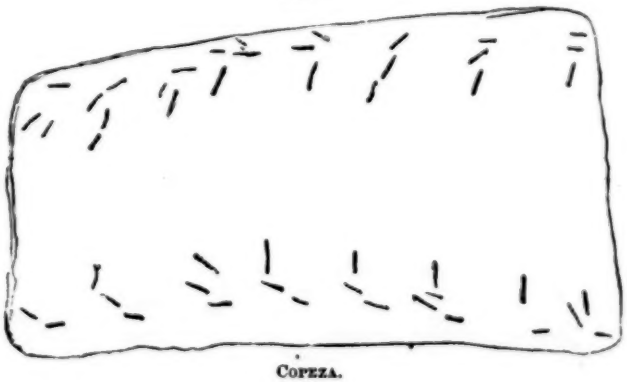
Whether arranged in order or clustered helter-skelter, these impressions cannot be distinguished from the mud-nests made every summer by existing tadpoles. Hence it is natural to suppose that the markings made at the different periods were produced by the same agency; and, as we know the origin of the latter, we may infer how the first came upon the rocks. The chief difficulty in the way of accepting this view lies in the perfect resemblance between them. If this doctrine is received, we must believe in the existence of tadpoles in the carboniferous rocks, because they contain similar relics. Those in the Triassic are remarkably distinct, making most beautiful specimens for the show-case.

The reference of the next group to the class of fishes may excite

surprise, for it is commonly supposed that these animals never leave the water for the land. It has been ascertained by naturalists that certain varieties of tropical fish often leave the water, and walk, or rather hobble, on the shore, using their fins for legs. This they can do for days together. They have also been known to climb trees in search of sustenance. Their track-way would be peculiar, consisting of two rows of dots or round impressions, made by the prominent sharp spine of the fin, accompanied by various trails produced by the shorter rays, body, and tail. One species of the *Ichnozoa* has made a trail so much like the markings of these tropical fish that we must believe the *Siluridæ* had other representatives in the Triassic waters. Another impression seems to have been made by an ordinary fish striking his fins against the ridges between ripple-marks in very shallow water.

With considerable hesitation, thirty-four species of *Ichnozoa* may be referred to *insects*. These animals generally have six feet. If attention be paid to the manner in which the common fly walks, it will appear that every foot is brought to the ground, each in a different place, so that every extremity makes a mark. A fly that has been immersed in a colored fluid, and then travels over a sheet of white paper, will leave impressions as distinct as those found upon stone, and the colored track-ways must be our guides to the affinities of the ancient ichnites, like the *Copeza*.

FIG. 5.



COPEZA.

Between these ancient and modern impressions it is difficult to find marked differences, except of size. Each displays two rows of impressions in groups of three, the several clusters alternating with one another. Of the three marks or lines in each cluster, the inner is almost at right angles with the line of march, the central and outer point backward, the latter the most.

We may suppose that each group of markings was made by the three feet on each side of the animal, the inner impressions by the

front pair of limbs, and the outer by the hindmost. Such groups would be preserved only under the most favorable circumstances. In many species the three pairs of legs might be of the same length, and two or more of the feet might tread upon the same spot, leaving but

FIG. 6.

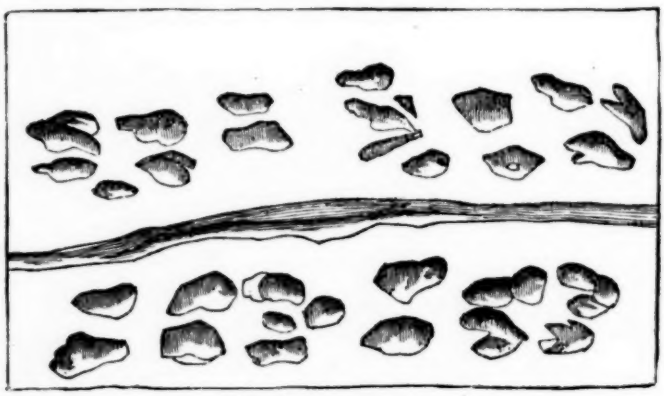
HAMIPES.

a single mark. Or the mud may have varied in its capacity for retaining the impressions, so that one or more rows may be wanting. Such cases are common among the *Ichnozoa*, so that track-ways very dissimilar to the unpractised eye are referred to the same species.

No attempt has been made to refer several ichnitic genera to the several orders of insects. With the small information now existing respecting insectean locomotion, such reference would be premature. It is very obvious that the selection must be made from groups frequenting the sea-shore at low tide.

Considering the lightness of these insects, or whatever animals

FIG. 7.



THE PROTOTICHNITES.

they may have been, it is remarkable that any part of these impressions should have been preserved. Only one good locality of them is known, upon a very fine-grained clayey rock, whose liquidity was sufficient to allow the marks to be made, and yet so solid that the heat of the sun evaporated the bulk of the water between the ebb and flow of a single tide. This locality is at the Lily Pond, Turner's Falls, near Greenfield, Massachusetts.

As might be expected, there was a group of *Crustaceans*, animals who frequent the mud left at low tide. Their impressions have been left on the rocks from the dawn of the Paleozoic age to the very latest period. The famous *Prototichnites* of Canada upon the Potsdam sandstone, so ably described by Logan and Owen, are generally thought to have been made by gigantic representatives of this class, though hardly by the *Pterogotus* form, as suggested by Salter and Woodward, because the latter were exclusively swimming animals. The *Prototichnites* were not represented in the Trias. The forms preserved at Amherst are peculiar, and not to be referred to any special order of Crustacea. One was a giant with a track-way 27 yards wide, and the idea suggested by its inspection is that of an animal with small body stilted high upon very long legs.

Other species of *Ichnozoa* may have been *Annelids*, with their sinuous, fimbriated line of march, *worms*, *mollusks*, with single, double, or treble depressed lines, and various larval forms—whether like those crawling over the surface or making burrows in the mud. A square rod of this Triassic surface will be as thoroughly carved by these various impressions, produced by the lower orders of animal life, as the same surface of the sea-shore in temperate or tropical climes at the present day.

Thus this brief review of the different classes of Triassic *Ichnozoa* shows a natural assemblage, such as might be found associated in maritime districts. The huge birds associated with kangaroo-like forms reminds us immediately of the modern Australian realm, with the cassowaries and the long list of marsupials. Indeed, it would not be strange if the assemblage of life which first showed itself in the American Triassic estuaries had gradually migrated eastward over regions now covered by the Northern Atlantic, pushing farther and farther in each geological era till the *ultima Thule* of Australia is reached, where the modern representatives of the *Ichnozoa* were prevented from further migration by the termination of continental areas. Soon after its occupation, Australia must have been separated from the Asiatic Continent by a partial submergence, so that the peculiar fauna became restricted, and none of the animals could retrace their steps toward the setting sun, even if they desired. It may be, then, that historic Australia represents Triassic New England in its faunal peculiarities—terrestrial, but not maritime, since marine animals cannot so easily be restricted in their migrations or developments.

Besides footprints, other markings on the Connecticut sandstone attract our attention. We observe the marks of rain-drops, ripples of the waves, shrinkage-cracks, broken bubbles arising from marsh-gas, septaria, rarely a shell, a possible echinoderm, coprolites of birds as determined by chemical analysis, a few reptilian bones, bark and cones of gymnosperms, besides other curious marine and terrestrial plants, remain.

The most interesting of these are the rain-drop impressions, particularly as they indicate the formation of the tracks of animals upon a surface not covered by water. Every rain-drop will leave a single round impression. They are preserved most perfectly when it barely sprinkles. In a heavy or long-continued shower so many impressions are made that they coalesce and leave no distinct trace of their existence. They might be said to resemble a chopped sea. None of the latter could be recognized upon the rock, even if they existed; but the sparsely-scattered impressions are abundantly, oftentimes elegantly, preserved.

Furthermore, when rain-drops are blown by the wind, they must fall upon the mud at an acute angle, greater or less in proportion to the force of the current. When a small stream of water is made to fall upon a hard, flat surface, it will be deflected, rising at the same angle, thus giving origin to the philosophical statement that the angle of incidence is equal to the angle of reflection. This principle is only partially exemplified by the Triassic phenomena, as the rain-drop is simply elongated in the direction of the wind. But these features illustrate the force and direction of the wind and the amount of the rainfall, so that we see the weather-cock and the rain-gauge of these ancient times. We find the fact impressed upon the strata in the same locality of a change in the course of the wind, showers, and storms, with, of course, intervals of sunshiny weather. Surely, then, the primitive times witnessed the same alternations of storm and sunshine that prevail at present.

The technical department of the science of Ichnology relates to a discussion of the characters derived from locomotion peculiar to each division of the animal kingdom. Certain distinctions are very obvious, such as the peculiarities of bipedal, quadrupedal, and multipedal locomotion. Bipedal tracks are chiefly of man, birds, and occasionally of the kangaroo-forms. So readily can these be distinguished that definitions are superfluous. The quadrupeds display hand-like feet, as the monkeys, rounded toes and heels like the dog, hoofs either single or cloven, and long, slender toes, few or numerous. Others, like the turtle and lizards, would show two rows of impressions, with short or long steps, and an occasional caudal mark. The lower forms of life would display a great variety of trails, loops, and hops; raised burrows in the mud, or vertical holes, and others of endless diversity. It is unnecessary to specify further the various locomotive characters by which the different groups may be recognized. That such exist may be considered as proved—some of them of very precise application. Not less than thirty different locomotive characters are made use of in the description of the New England ichnitic fauna. Further investigations must add to their number and definiteness, and consequently to the value of ichnological studies.

Cuvier has finely described the definiteness and certainty with

which we can infer the character of an animal from its track, though, when he wrote, fossil foot-marks were unknown. "Any one," says he, "who observes merely the print of a cloven hoof, may conclude that it has been left by a ruminant animal, and regard the conclusion as equally certain with any other in physics or morals. Consequently, this single footmark clearly indicates to the observer the forms of the teeth, of all the leg-bones, thighs, shoulders, and of the trunk of the body of the animal which left the mark. It is much surer than all the marks of Zadig."

The contemplation of fossil foot-marks may suggest important moral lessons. To leave their names inscribed on the world's history is a universal desire of mankind. To accomplish this object, various methods have been devised; comfort, health, life, and even moral principle, have been sacrificed, and yet the actor has been unable to crawl into the remotest corner of history. There have been conquerors bathing their limbs in the blood of the slain; kings, who have erected towers, pyramids, and cities; authors, who have composed elaborate and learned treatises; gigantic intellects, who have moulded the characters of nations—and yet no traces of their individual names or memories remain to posterity. All of these may have spurned the reptiles crawling beneath their feet; yet the lower orders of animal life—such as flourished hundreds of thousands of years since, before the surface of the earth was fitted for the residence of man—have left memorials of their passage enduring and indelible.

Those who would benefit their fellow-men need not despair. Those senseless tribes had only dead matter to work upon, and the touch of a hammer may ruthlessly destroy what has endured for ages, and it can never be repaired. But man can influence the living mind, imparting lessons that will outlast, in their influence, both time and fate. Then let all our actions be upright, and we shall thus—

——"departing, leave behind us
Footprints on the sands of time."

THE NATURE AND INFLUENCE OF FOODS.[1]

By EDWARD SMITH, M. D., F. R. S.

BEFORE proceeding to consider the numerous foods which will come under review in the course of this work, it seems desirable to offer a few remarks of a general character on their nature and qualities, and the necessity for them.

As a general definition, it may be stated that a food is a substance

[1] From the introductory chapter of the International Scientific Series, No. III., "On Foods."

which, when introduced into the body, supplies material which renews some structure or maintains some vital process; and it is distinguished from a medicine in that the latter modifies some vital action, but does not supply the material which sustains such action.

This is certainly correct so far as relates to the substances which supply nearly all our nourishment, and which the Germans class under the term *Nahrungsmittel*, but there are certain so-called foods known as *Genussmittel*, which seem to form a connecting link, in that they increase vital actions in a degree far beyond the amount of nutritive material which they supply. They thus resemble certain medicines in their action, but, as they supply a proportion of nutritive material, they should be ranked as foods.

It is essential to the idea of a food that it should support or increase vital actions; while medicines usually lessen, but may increase, some of them.

It is not necessary that a food should yield every kind of material which the body requires, for then one might suffice for the wants of man, but that it fulfils one or more of such requirements, so that by a combination of foods the whole wants of the body may be supplied. Neither is it essential that every food should be decomposed or broken up, and its elements caused to enter into new combinations when forming or maintaining the structures of the body, since there are some which in their nature are identical with parts of the body, and, being introduced, may be incorporated with little or no change.

But there are foods which are more valuable to the body than others, in that they supply a greater number of the substances which it requires, and such are known as compound foods, while others, which supply but one element, or which are incorporated without change, may be termed simple foods. Other foods are more valuable because they are more readily changed into the substance of the body, or act more readily and quickly in sustaining vital actions, and these may be called easily-digested or easily-assimilated foods. Others are preferred because they supply a greater quantity of useful nutriment at a less proportionate cost, and are known as economical foods; and foods varying in flavor are classed as more or less agreeable foods.

Some foods are classed according to the source whence they are derived, as animal and vegetable foods; and others according to the density of their substance, as fluid and solid foods.

There are foods which nourish one part of the body only, and others which sustain one chief vital action, and are called flesh-forming or heat-forming foods, while others combine both qualities.

Besides these larger divisions, there are qualities in foods which permit of further classification, such as those which render them particularly fit for different ages, climates, and seasons, and others which possess a special character, as sweetness, acidity, or bitterness.

There are also effects produced by foods apart from or in addition

to those of nutrition, which are not common to all; so that some foods more than others influence the action of the heart, lungs, skin, brain, bowels, or other vital organ, while others have antagonistic qualities, so that one may destroy certain effects of another.

Foods are derived from all the great divisions of Nature and natural products, as earth, water, and air, solids, liquids, and gases; and from substances which are living and organic, or inanimate and inorganic. The popular notion of food as a solid substance derived from animals and vegetables, while comprehensive, is too exclusive, since the water which we drink, the air which we breathe, and certain minerals found in the substance of the earth, are of no less importance as foods.

It is, however, of great interest to note how frequently all these are combined in one food, and how closely united are substances which seem to be widely separated. Thus water and minerals are found in both flesh and vegetables, while one or both of the component parts of the air, viz., oxygen and nitrogen, are distributed through every kind of food. Hence, not only may we add food to food to supply the wants of the body, but we may within certain limits substitute one for another as our appetites or wants demand. The necessity for this in the economy of Nature is evident, for, although a good Providence has given to man an almost infinite number of foods, all are not found everywhere, neither can any man obtain all foods found around him.

Further, there seems to be an indissoluble bond existing between all the sources of food. There are the same classes of elements in flesh as in flour, and the same in animals as in vegetables. The vegetable draws water and minerals from the soil, while it absorbs and incorporates the air in its own growth, and is then eaten to sustain the life of animals, so that animals gain the substances which the vegetable first acquired. But, in completing the circle, the vegetable receives from the animal the air which was thrown out in respiration, and lives and grows upon it, and at length the animal itself, in whole or in part, and the refuse which it daily throws off, become the food of the vegetable. Even the very bones of an animal are by the aid of Nature or man made to increase the growth of vegetables, and really to enter into their structure; and, being again eaten, animals may be said to eat their own bones and live on their own flesh. Hence there is not only an unbroken circle in the production of food from different sources, but even the same food may be shown to be produced from itself. Surely this is an illustration of the fable of the young phœnix arising from the ashes of its parent!

Food is required by the body for two chief purposes, viz., to generate heat and to produce and maintain the structures under the influence of life and exertion. The importance of the latter is the more apparent, since wasting of the body is familiarly associated with decay of life; but the former is so much the more urgent, that, whereas

the body may waste for a lengthened period and yet live, it rapidly dies when the source of heat is removed or even greatly lessened.

The production of heat in the body, so wonderful in the process and amount, results only from the chemical combination of the elements of food, whether on the minute scale of the atoms of the several tissues, or on the larger one connected with respiration, and is thence called the combustion of food. As familiar illustrations of the production of heat from chemical change, we may mention that, when cold oil of vitriol and cold water are added together, the mixture becomes so hot that the hand cannot bear it, and the heating of haystacks, and also of barley in the process of malting, is well known. This action in the body is not restricted to changes in one element alone, but proceeds with all; yet it is chiefly due to a combination of three elements, viz., oxygen, hydrogen, and carbon, and requires for its support fat, starch, or sugar, or other digestible food composed of those substances, precisely as coal and wood supply fuel for fire without the body.

This effect is made extremely striking, by Prof. Frankland, in the following table, which shows the amount of heat generated from so small a quantity as ten grains of certain foods during their complete combustion within the body, and the force which scientific calculations have shown to be equivalent to that amount of heat. The original quantity used by Prof. Frankland has been reduced by Dr. Letheby to ten grains, for the convenience of English readers:

No. 1.

FOOD.	In combustion raises lbs. of water 1 degree Fahr.	Which is equal to lifting lbs. 1 foot high.
10 grains of dry flesh	13.12	10,128
" " albumen	12.85	9,920
" " lump-sugar	8.61	6,647
" " arrow-root	10.06	7,766
" " butter	18.68	14,421
" " beef-fat	20.91	16,142

Thus we prove that an ounce of fresh lean meat, if entirely burned in the body, would produce heat sufficient to raise about 70 lbs. of water 1° Fahr., or a gallon of water about 7° Fahr. In like manner, one ounce of fresh butter would produce ten times that amount of heat; but it must be added that, as the combustion which is effected within the body is not always complete, the actual effect is less than that now indicated.

It may thus be shown that the division of foods into the two great classes of flesh-formers and heat-generators is not to be taken too incisively, for while a food is renewing flesh it also produces heat, and while the heat-generating food is acting it may also produce a part of flesh in the form of fat; but, although they are so closely associated

in their vital work, the leading characteristic of each kind is so marked as to warrant the classification which Liebig has formulated.

It is understood that the structures of the body are in a state of continual change, so that atoms which are present at one hour may be gone the next, and, when gone, the structures will be so far wasted, unless the process of waste be accompanied by renewal. But the renewing substance must be of the same nature as that wasted, so that bone shall be renewed by bone and flesh by flesh; and hence, while the body is always changing, it is always the same. This is the duty assigned to food—to supply to each part of the body the very same kind of material that is lost by waste.

As foods must have the same composition as the body, or supply such other materials as by vital action may be transformed into the substances of the body, it is desirable to gain a general idea of what these substances are.

The following is a summary statement of the principal materials of which the body is composed:

Flesh in its fresh state contains water, fat, fibrine, albumen, and gelatine, besides compounds of lime, phosphorus, soda, potash, magnesia, silica, and iron, and certain extractives.

Blood has a composition similar in elements to that of flesh.

Bone is composed of cartilage, gelatine, fat, and salts of lime, magnesia, soda, and potash, combined with phosphoric and other acids.

Cartilage consists of chondrine, which is like gelatine in composition, with salts of soda, potash, lime, phosphorus, magnesia, sulphur, and iron.

The brain is composed of water, albumen, fat, phosphoric acid, osmazome, and salts.

The liver consists of water, fat, and albumen, with phosphoric and other acids in conjunction with soda, lime, potash, and iron.

The lungs are formed of a substance resembling gelatine, albumen, a substance analogous to caseine, fibrine, various fatty and organic acids, cholesterine, with salts of soda, and iron and water.

Bile consists of water, fat, resin, sugar, fatty and organic acids, cholesterine, and salts of potash, soda, and iron.

Hence it is requisite that the body should be provided with salts of potash, soda, lime, magnesia, sulphur, iron, and manganese, as well as sulphuric, hydrochloric, phosphoric, and fluoric acids and water; also nearly all the fat which it consumes daily, and probably all the nitrogenous substances which it requires, and which are closely allied in composition, as albumen, fibrine, gelatine, and chondrine. It can produce sugar rapidly and largely, and fat slowly and sparely, from other substances; also lactic, acetic, and various organic acids, and peculiar extractive matters.

So great an array of mysterious substances might well prevent us from feeding ourselves or others if the selection of food depended solely upon our knowledge and judgment; but it is not so, for, inde-

pendently of the aid derived from our appetites, there is the great advantage of having foods which contain a proportion of nearly all these elements; and combinations of foods have been effected by experience which protect even the most ignorant from evil consequences.

Thus flesh, or the muscular tissue of animals, contains precisely the elements which are required in our flesh-formers, and, only limited by quantity, our heat-generators also; and life may be maintained for very lengthened periods upon that food and water when eaten in large quantities. Seeing, moreover, that the source of flesh in animals which are used as food is vegetables, it follows that vegetables should have the same elements as flesh, and it is a fact of great interest that in vegetables we have foods closely analogous to the flesh of animals. Thus, in addition to water and salts, common to both, there is vegetable jelly, vegetable albumen, vegetable fibrine, and vegetable caseine, all having a composition almost identical with animal albumen, gelatine, chondrine, and caseine.

Hence our appetites and the bountiful provision made for us extend our choice to both the vegetable and animal kingdoms, and it is possible to find vegetable foods on which man could live as long as upon animal food alone. Bread is in vegetable foods that which flesh is in animal foods, and each within itself contains nearly all the elements required for nutrition.

When, however, we bring knowledge of a special kind to the aid of our appetites, we are able to discover both the deficiencies in any given food and the kind of food which would meet them. Thus a knowledge of the requirements of the system and of the available uses of food leads to the proper combinations of food, or to the construction of dietaries.

We have thus placed face to face the requirements of the body and the qualities of the foods to be used to supply them, but it is of very common observation that the effect of the supply is but temporary, and needs renewal at definite periods. Hence we show that the needs of the body are tolerably uniform, while the effect of the supply is temporary, or that both the need and the supply are intermittent. This may be readily represented by showing the line of change in the degree of vital action on the body during the twenty-four hours, as produced by my own investigations, and delineated in the graphic diagrams of the present work.

It is there illustrated that, during the repose of the night, the amount of vital action, as shown by the respiration and pulsation, is low and tolerably uniform, while under the influence of food it is high, and varies during the day extremely, but the general course is such that a large increase takes place after a meal, and a considerable decrease before the following meal. This increase, followed by decrease, being due to the action of food, proves that the influence is temporary, and that after a sufficient interval another supply of food is required.

At the same time it must be allowed that the body is not entirely a passive agent subject to the controlling action of food, for no supply could prevent the vital actions subsiding at night, or make them equal both by night and day.

There is a power inherent in the body which accepts or rejects food as to amount, as well as to quality, and which might at length act through the appetite, and refuse the kind supplied. Moreover, the wants of the body vary from many other well-known influences, and cause an increase or decrease in the vital actions which proceeds *pari passu* with the consumption of the transformed or stored-up food in a degree proportionate to the cause, but such effects are often more rapid and transitory than that of food.

The variations in the requirement for food are induced by age, climate, season, and degree of exertion, and will be more fully discussed in the work on Dietaries; but it may now be desirable to give a glance at some of them.

In reference to age, there can be no doubt that all vital processes, including the action of foods, are greater and more rapid in early, and less and slower in later, than in mature life, and in both the former a more frequent administration of food is necessary. In early life, moreover, there is the important function of growth, which demands a large and more frequent supply of food, not only for daily wants, but to promote a due increase in the bulk of the structures of the body. I have also shown that the season of the year has also a decided influence over the vital actions, so that they are the greatest in the spring and the least at the end of summer.

The action of climate is similar to that of season, and shows that the vital actions are greater in cold than in hot climates, and in the uplands than in close valleys.

The influence of exertion over vital changes is immediate and proportionate, while the subsidence with the rest is less rapid than the increase. The following table of experiments upon myself shows the proportionate effect of exertion of varying degrees on the basis of the increased volume of air inspired:

No. 6.

The lying posture	being	1
The sitting posture	is	1.18
Reading aloud or singing	"	1.26
The standing posture	"	1.33
Railway travelling in the 1st class	"	1.40
" " " 2d class	"	1.5
" " upon the engine, at 20 to 30 miles per hour	"	1.52
" " " " 50 to 60 " "	"	1.55
" " in the 3d class	"	1.58
" " upon the engine, average of all speeds	"	1.58
" " " " at 40 to 50 miles per hour	"	1.61
" " " " 30 to 40 " "	"	1.64

Walking in the sea	is	1.65
" on land at 1 mile per hour	"	1.9
Riding on horseback at the walking pace	"	2 2
Walking at 2 miles per hour	"	2.76
Riding on horseback at the cantering pace	"	3.16
Walking at 3 miles per hour	"	3.22
Riding moderately	"	3.33
Descending steps at 640 yards perpendicular per hour	"	3.43
Walking at 3 miles per hour and carrying 34 lbs.	"	3.5
" " " " 62 lbs.	"	3.84
Riding on horseback at the trotting pace	"	4.05
Swimming at good speed	"	4.33
Ascending steps at 640 yards perpendicular per hour	"	4.4
Walking at 3 miles per hour and carrying 118 lbs.	"	4.75
" 4 miles per hour	"	5.0
The tread-wheel, ascending 45 steps per minute	"	5.5
Running at 6 miles per hour	"	7.0

Another table, from the same series of experiments, illustrates the same effect on the basis of the amount of carbonic acid evolved by respiration per minute:

No. 7.

In profound sleep, lying posture	4.5 grains.
In light sleep, "	4.99 "
Scarcely awake, 1½ A. M.	5.7 "
" " 2½ "	5.94 "
" " 6¼ "	6.1 "
Walking at 2 miles per hour	18.1 "
" 3 " "	25.83 "
Tread-wheel, ascending 28.15 feet per minute	43.36 "

Thus it is possible that the amount of vital change proceeding in the body may be ten times greater in one state than in another, and it follows that a proportionate quantity of food will be required to sustain it.

LUNAR TEMPERATURES.

POETS have so long sung of the cold, chaste Moon, pallid with weariness of her long watch upon the Earth (according to the image used alike by Wordsworth and Shelley), that it seems strange to learn from science that the full moon is so intensely hot that no creature known to us could long endure contact with her heated surface. Such is the latest news which science has brought us respecting our satellite. The news is not altogether unexpected; in fact, reasoning had shown, long before the fact had been demonstrated, that it must be so. The astronomer knows that the surface of the moon is exposed during the long lunar day, lasting a fortnight of our terrestrial time, to the rays of a sun as powerful as that which gives us our daily heat.

Without an atmosphere to temper the sun's heat as ours does—not, indeed, by impeding the passage of the solar rays, but by bearing aloft the cloud-veil which the sun raises from our oceans—the moon's surface must become intensely hot long before the middle of the lunar day. Undoubtedly the want of an atmosphere causes the moon's heat to be rapidly radiated away into space. It is our atmosphere which causes a steady heat to prevail on our earth. And at the summits of lofty mountains, where the atmosphere is rare, although the mid-day heat is intense, yet so rapidly does the heat pass away that snow crowns forever the mountain-heights. Yet, although the moon's heat must pass away even more rapidly, this does not prevent the heating of the moon's actual surface, any more than the rarity of the air prevents the Alpine traveller from feeling the action of the sun's direct heat even when the air in shadow is icily cold. Accordingly, Sir John Herschel long since pointed out that the moon's surface must be heated at lunar mid-day—or rather, at the time of lunar mid-heat, corresponding to about two o'clock in our afternoon—to a degree probably surpassing the heat of boiling water.

Such, in point of fact, has now been proved to be the case. The Earl of Rosse has shown, by experiments which need not here be described, that the moon not only reflects heat to the earth (which, of course, must be the case), but that she gives out heat by which she has been herself warmed. The distinction may not perhaps appear clear at first sight to every reader, but it may easily be explained and illustrated. If, on a bright summer's day, we take a piece of smooth, but not too well polished, metal, and by means of it reflect the sun's light upon the face, a sensation of heat will be experienced; this is reflected sun-heat: but if we wait while so holding the metal until the plate has become quite hot under the solar rays, we shall recognize a sensation of heat from the mere proximity of the plate to the face, even when the plate is so held as not to reflect sun-heat. We can in succession try—first, reflected heat alone, before the metal has grown hot; next, the heat which the metal gives out of itself when warmed by the sun's rays; and, lastly, the two kinds of heat together, when the metal is caused to reflect sun-heat, and also (being held near the face) to give out a sensible quantity of its own warmth. What Lord Rosse has done has been to show that the full moon sends earthward both kinds of heat; she reflects solar heat just as she reflects solar light, and she also gives out the heat by which her own surface has been warmed.

It may perhaps occur to the reader to inquire how much heat we actually obtain from the full moon. There is a simple way of viewing the matter. If the full moon were exactly as hot as boiling water, we should receive from her just as much heat (leaving the effect of our atmosphere out of account) as we should receive from a small globe as hot as boiling water, and at such a distance as to *look* just as large

as the moon does. Or a disk of metal would serve equally well. Now, the experiment may be easily tried. A bronze halfpenny is exactly one inch in diameter, and as the moon's average distance is about 111 times her own diameter, a halfpenny at a distance of 111 inches, or three yards and three inches, looks just as large as the moon. Now let a halfpenny be put in boiling water for a while, so that it becomes as hot as the water; then that coin taken quickly and set three yards from the observer will give out, for the few moments that its heat remains appreciably that of boiling water, as much heat to the observer as he receives from the full moon supposed to be as hot as boiling water. Or a globe of thin metal, one inch in diameter and full of water at boiling-heat, would serve as a more constant artificial moon in respect of heat-supply. It need not be thought remarkable, then, if the heat given out by the full moon is not easily measured, or even recognized. Imagine how little the cold of a winter's day would be relieved by the presence, in a room no otherwise warmed, of a one-inch globe of boiling water, three yards away! And, by-the-way, we are here reminded of an estimate by Prof. C. B. Smyth, resulting from observations made on the moon's heat during his Teneriffe experiments. He found the heat equal to that emitted by the hand at a distance of three feet.

But, after all, the most interesting results flowing from the recent researches are those which relate to the moon herself. We cannot but speculate on the condition of a world so strangely circumstanced that a cold more bitter than that of our arctic nights alternates with a heat exceeding that of boiling water. It is strange to think that the calm-looking moon is exposed to such extraordinary vicissitudes. There can scarcely be life in any part of the moon—unless it be underground life, like that of the Modoc Indians (we commend this idea specially to the more ardent advocates of Brewsterian ideas respecting other worlds than ours). And yet there must be a singularly active mechanical process at work in yonder orb. The moon's substance must expand and contract marvellously as the alternate waves of heat and cold pass over it. The material of that crater-covered surface must be positively crumbling away under the effects of these expansions and contractions. The most plastic terrestrial substances could not long endure such processes, and it seems altogether unlikely that any part of the moon's crust is at all plastic. Can we wonder if, from time to time, astronomers tell us of apparent changes in the moon—a wall sinking here, or a crater vanishing elsewhere? The wonder rather is, that the steep and lofty lunar mountains have not been shaken long since to their very foundations.

Our moon presents, in fact, a strange problem for our investigation. It is gratifying to us terrestrials to regard her as a mere satellite of the earth, but in reality she deserves rather to be regarded as companion planet. She follows a path round the sun which so nearly

resembles that pursued by the earth, in shape as well as in extent, that, if the two paths were traced down on a quarto sheet, it would not be easy to distinguish one from the other. Our earth is simply the largest, while the moon is the smallest of that inner family of worlds over which the sun bears special sway, nor does Mercury exceed the moon to so great a degree in mass and in volume as the earth or Venus exceeds Mercury. Yet the moon, with her surface of 14,000,000 square miles, seems to be beyond a doubt a mere desert waste, without air or water, exposed to alternations of heat and cold which no living creature we are acquainted with could endure; and notwithstanding her position as an important member of the solar system, as well as the undoubted fact that in her motions she obeys the sun in preference to the earth, she has nevertheless been so far coerced by the earth's influence as to be compelled to turn always the same face toward her larger companion orb, so that not a ray from the earth ever falls upon fully 5,000,000 square miles of the farther lunar hemisphere. A waste of matter here, we might say, and a waste of all the energy which is represented by the moon's motions, did we not remember that we can see but a little way into the plan of Creation, and that what appears to us waste may in reality be an essential and important part of the great scheme of Nature.—*Spectator.*

THE PROBLEMS OF THE DEEP SEA.

By Prof. T. H. HUXLEY, LL. D., F. R. S.

ON the 21st of December, 1872, H. M. S. Challenger, an eighteen-gun corvette, of 2,000 tons burden, sailed from Portsmouth harbor for a three, or perhaps four, years' cruise. No man-of-war ever left that famous port before with so singular an equipment. Two of the eighteen sixty-eight pounders of the Challenger's armament remained to enable her to speak with effect to sea-rovers, haply devoid of any respect for science, in the remote seas for which she is bound; but the main-deck was, for the most part, stripped of its warlike gear, and fitted up with physical, chemical, and biological laboratories; photography had its dark cabin; while apparatus for dredging, trawling, and sounding; for photometers and for thermometers, filled the space formerly occupied by guns and gun-tackle, pistols and cutlasses.

The crew of the Challenger match her fittings. Captain Nares, his officers and men, are ready to look after the interests of hydrography, work the ship, and, if need be, fight her as seamen should; while there is a staff of scientific civilians, under the general direction

of Dr. Wyville Thomson, F. R. S. (Professor of Natural History in Edinburgh University by rights, but at present detached for duty *in partibus*), whose business it is to turn all the wonderfully-packed stores of appliances to account, and to accumulate, before the ship returns to England, such additions to natural knowledge as shall justify the labor and cost involved in the fitting out and maintenance of the expedition.

Under the able and zealous superintendence of the hydrographer, Admiral Richards, every precaution which experience and forethought could devise has been taken to provide the expedition with the material conditions of success; and it would seem as if nothing short of wreck or pestilence, both most improbable contingencies, could prevent the Challenger from doing splendid work, and opening up a new era in the history of scientific voyages.

The dispatch of this expedition is the culmination of a series of such enterprises, gradually increasing in magnitude and importance, which the Admiralty, greatly to its credit, has carried out for some years past; and the history of which is given by Dr. Wyville Thomson in the beautifully-illustrated volume entitled "The Depths of the Sea," published since his departure:

"In the spring of the year 1868, my friend Dr. W. B. Carpenter, at that time one of the vice-presidents of the Royal Society, was with me in Ireland, where we were working out together the structure and development of the Crinoids. I had long previously had a profound conviction that the land of promise for the naturalist, the only remaining region where there were endless novelties of extraordinary interest ready to the hand which had the means of gathering them, was the bottom of the deep sea. I had even had a glimpse of some of these treasures, for I had seen, the year before, with Prof. Sars, the forms which I have already mentioned, dredged by his son at a depth of 300 to 400 fathoms off the Loffoden Islands. I propounded my views to my fellow-laborer, and we discussed the subject many times over our microscopes. I strongly urged Dr. Carpenter to use his influence at headquarters to induce the Admiralty, probably through the Council of the Royal Society, to give us the use of a vessel properly fitted with a dredging-gear and all necessary scientific apparatus, that many heavy questions as to the state of things in the depths of the ocean, which were still in a state of uncertainty, might be definitely settled. After full consideration, Dr. Carpenter promised his hearty coöperation, and we agreed that I should write to him on his return to London, indicating generally the results which I anticipated, and sketching out what I conceived to be a promising line of inquiry. The Council of the Royal Society warmly supported the proposal; and I give here in chronological order the short and eminently satisfactory correspondence which led to the Admiralty placing at the disposal of Dr. Carpenter and myself the gunboat Lightning, under the command of Staff-Commander May, R. N., in the summer of 1868, for a trial cruise to the north of Scotland, and afterward to the much wider surveys in H. M. S. Porcupine, Captain Calver, R. N., which were made with the additional association of Mr. Gwyn Jeffreys, in the summers of the years 1869 and 1870."[1]

[1] "The Depths of the Sea," pp. 49, 50.

Plain men may be puzzled to understand why Dr. Wyville Thomson, not being a cynic, should relegate the "Land of Promise" to the bottom of the deep sea; they may still more wonder what manner of "milk and honey" the Challenger expects to find; and their perplexity may well rise to its maximum, when they seek to divine the manner in which that milk and honey are to be got out of so inaccessible a Canaan. I will, therefore, endeavor to give some answer to these questions in an order the reverse of that in which I have stated them.

Apart from hooks, and lines, and ordinary nets, fishermen have, from time immemorial, made use of two kinds of implements for getting at sea-creatures which live beyond tide-marks—these are the "dredge" and the "trawl." The dredge is used by oyster-fishermen. Imagine a large bag, the mouth of which has the shape of an elongated parallelogram, and is fastened to an iron frame of the same shape, the two long sides of this rim being fashioned into scrapers. Chains attach the ends of the frame to a stout rope, so that when the bag is dragged along by the rope, the edge of one of the scrapers rests on the ground, and scrapes whatever it touches into the bag. The oyster-dredger takes one of these machines in his boat, and when he has reached the oyster-bed the dredge is tossed overboard; as soon as it has sunk to the bottom, the rope is paid out sufficiently to prevent it from pulling the dredge directly upward, and is then made fast while the boat goes ahead. The dredge is thus dragged along and scrapes oysters and other sea-animals and plants, stones, and mud into the bag. When the dredger judges it to be full he hauls it up, picks out the oysters, throws the rest overboard, and begins again.

Dredging in shallow water, say ten to twenty fathoms, is an easy operation enough; but the deeper the dredger goes, the heavier must be his vessel, and the stouter his tackle, while the operation of hauling up becomes more and more laborious. Dredging in 150 fathoms is very hard work, if it has to be carried on by manual labor; but by the use of the donkey-engine to supply power,[1] and of the contrivances known as "accumulators," to diminish the risk of snapping the dredge-rope by the rolling and pitching of the vessel, the dredge has been worked deeper and deeper, until at last, on the 22d of July, 1869, H. M. S. Porcupine being in the Bay of Biscay, Captain Calver, her commander, performed the unprecedented feat of dredging in 2,435 fathoms, or 14,610 feet, a depth nearly equal to the height of Mont Blanc. The dredge "was rapidly hauled on deck at one o'clock in the morning of the 23d, after an absence of 7¼ hours, and a journey of

[1] The emotional side of the scientific nature has its singularities. Many persons will call to mind a certain philosopher's tenderness over his watch—"the little creature"—which was so singularly lost and found again. But Dr. Wyville Thomson surpasses the owner of the watch in his loving-kindness toward a donkey-engine. "This little engine was the comfort of our lives. Once or twice it was overstrained, and then we pitied the willing little thing, panting like an overtaxed horse."

upward of eight statute miles," with a hundred-weight and a half of solid contents.

The trawl is a sort of net for catching those fish which habitually live at the bottom of the sea, such as soles, plaice, turbot, and gurnett. The mouth of the net may be thirty or forty feet wide, and one edge of its mouth is fastened to a beam of wood of the same length. The two ends of the beam are supported by curved pieces of iron, which raise the beam and the edge of the net which is fastened to it, for a short distance, while the other edge of the mouth of the net trails upon the ground. The closed end of the net has the form of a great pouch; and, as the beam is dragged along, the fish, roused from the bottom by the sweeping of the net, readily pass into its mouth and accumulate in the pouch at its end. After drifting with the tide for six or seven hours the trawl is hauled up, the marketable fish are picked out, the others thrown away, and the trawl sent overboard for another operation.

More than a thousand sail of well-found trawlers are constantly engaged in sweeping the seas around our coast in this way, and it is to them that we owe a very large proportion of our supply of fish. The difficulty of trawling, like that of dredging, rapidly increases with the depth at which the operation is performed; and, until the other day, it is probable that trawling at so great a depth as 100 fathoms was something unheard of. But the first news from the Challenger opens up new possibilities for the trawl.

Dr. Wyville Thomson writes (*Nature*, March 20, 1873):

"For the first two or three hauls in very deep water off the coast of Portugal, the dredge came up filled with the usual 'Atlantic ooze,' tenacious and uniform throughout, and the work of hours, in sifting, gave the very smallest possible result. We were extremely anxious to get some idea of the general character of the Fauna, and particularly of the distribution of the higher groups; and, after various suggestions for modification of the dredge, it was proposed to try the ordinary trawl. We had a compact trawl, with a 15-feet beam, on board, and we sent it down off Cape St. Vincent at a depth of 600 fathoms. The experiment looked hazardous, but, to our great satisfaction, the trawl came up all right, and contained, with many of the larger invertebrata, several fishes. . . . After the first attempt we tried the trawl several times at depths of 1,090, 1,525, and, finally, 2,125 fathoms, and always with success."

To the coral-fishers of the Mediterranean, who seek the precious red coral, which grows firmly fixed to rocks at a depth of sixty to eighty fathoms, both the dredge and the trawl would be useless. They, therefore, have recourse to a sort of frame, to which are fastened long bundles of loosely-netted hempen cord, and which is lowered by a rope to the depth at which the hempen cords can sweep over the surface of the rocks and break off the coral, which is brought up entangled in the cords. A similar contrivance has arisen out of the necessities of deep-sea exploration.

In the course of the dredging of the Porcupine, it was frequently found that, while few objects of interest were brought up within the dredge, many living creatures came up sticking to the outside of the dredge-bag, and even to the first few fathoms of the dredge-rope. The mouth of the dredge doubtless rapidly filled with mud, and thus the things it should have brought up were shut out. To remedy this inconvenience Captain Calver devised an arrangement not unlike that employed by the coral-fishers. He fastened half a dozen swabs, such as are used for drying decks, to the dredge. A swab is something like what a birch-broom would be if its twigs were made of long, coarse hempen yarns. These dragged along after the dredge over the surface of the mud, and entangled the creatures living there—multitudes of which, twisted up in the strands of the swabs, were brought to the surface with the dredge. A further improvement was made by attaching a long iron bar to the bottom of the dredge-bag, and fastening large bunches of teased-out hemp to the end of this bar. These "tangles" brought up immense quantities of such animals as have long arms, or spines, or prominences which readily become caught in the hemp, but they are very destructive to the fragile organisms which they imprison; and, now that the trawl can be successfully worked at the greatest depths, it may be expected to supersede them; at least, wherever the ground is soft enough to permit of trawling.

It is obvious that between the dredge, the trawl, and the tangles, there is little chance for any organism, except such as are able to burrow rapidly, to remain safely at the bottom of any part of the sea which the Challenger undertakes to explore. And, for the first time in the history of scientific exploration, we have a fair chance of learning what the population of the depths of the sea is like in the most widely-different parts of the world.

And now arises the next question. The means of exploration being fairly adequate, what forms of life may be looked for at these vast depths?

The systematic study of the Distribution of living beings is the most modern branch of Biological Science, and came into existence long after Morphology and Physiology had attained a considerable development. This naturally does not imply that, from the time men began to observe natural phenomena, they were ignorant of the fact that the animals and plants of one part of the world are different from those in other regions; or that those of the hills are different from those of the plains in the same region; or, finally, that some marine creatures are found only in the shallows, while others inhabit the deeps. Nevertheless, it was only after the discovery of America that the attention of naturalists was powerfully drawn to the wonderful differences between the animal population of the central and southern parts of the New World and that of those parts of the Old World which lie under the same parallels of latitude. So far back as 1667 Abraham

Mylius, in his treatise "*De Animalium origine et migratione populorum*," argues that, since there are innumerable species of animals in America which do not exist elsewhere, they must have been made and placed there by the Deity: Buffon no less forcibly insists upon the difference between the Faunæ of the Old and New World. But the first attempt to gather facts of this order into a whole, and to coördinate them into a series of generalizations, or laws of Geographical Distribution, is not a century old, and is contained in the "Specimen Zoologiæ Geographicæ Quadrupedum Domicilia et Migrationes sistens," published, in 1777, by the learned Brunswick professor, Eberhard Zimmermann, who illustrates his work by what he calls a "Tabula Zoographica," which is the oldest distributional map known to me.

In regard to matters of fact, Zimmermann's chief aim is to show that, among terrestrial mammals, some occur all over the world, while others are restricted to particular areas of greater or smaller extent; and that the abundance of species follows temperature, being greatest in warm and least in cold climates. But marine animals, he thinks, obey no such law. The Arctic and Atlantic Seas, he says, are as full of fishes and other animals as those of the tropics. It is, therefore, clear that cold does not affect the dwellers in the sea as it does land animals, and that this must be the case follows from the fact that sea-water, "propter varias quas continet bituminis spiritusque particulas," freezes with much more difficulty than fresh water. On the other hand, the heat of the Equatorial sun penetrates but a short distance below the surface of the ocean. Moreover, according to Zimmermann, the incessant disturbance of the mass of the sea, by winds and tides, so mixes up the warm and the cold that life is evenly diffused and abundant throughout the ocean.

In 1810, Risso, in his work on the Ichthyology of Nice, laid the foundation of what has since been termed "bathymetrical" distribution, or distribution in depth, by showing that regions of the sea-bottom of different depths could be distinguished by the fishes which inhabit them. There was the *littoral region* between tide-marks with its sand-eels, pipe-fishes, and blennies; the *sea-weed region*, extending from low water-mark to a depth of 450 feet, with its wrasses, rays, and flat-fish; and the *deep-sea region*, from 450 feet to 1,500 feet or more, with its file-fish, sharks, gurnards, cod, and sword-fish.

More than twenty years later, MM. Audouin and Milne Edwards carried out the principle of distinguishing the Faunæ of different zones of depth much more minutely, in their "Recherches pour servir à l'Histoire Naturelle du Littoral de la France," published in 1832.

They divide the area included between high-water mark and low-water mark of spring tides (which is very extensive, on account of the great rise and fall of the tide on the Normandy coast about St. Malo, where the observations were made) into four zones, each characterized by its peculiar invertebrate inhabitants. Beyond the fourth

region they distinguish a fifth, which is never uncovered, and is inhabited by oysters, scallops, and large starfishes and other animals. Beyond this they seem to think that animal life is absent.[1]

Audouin and Milne Edwards were the first to see the importance of the bearing of a knowledge of the manner in which marine animals are distributed in depth, on geology. They suggest that, by this means, it will be possible to judge whether a fossiliferous stratum was formed upon the shore of an ancient sea, and even to determine whether it was deposited in shallower or deeper water on that shore; the association of shells or animals which live in different zones of depth will prove that the shells have been transported into the position in which they are found; while, on the other hand, the absence of shells in a deposit will not justify the conclusion that the waters in which it was formed were devoid of animal inhabitants, inasmuch as they might have been only too deep for habitation.

The new line of investigation thus opened by the French naturalists was followed up by the Norwegian, Sars, in 1835, by Edward Forbes, in our own country, in 1840,[2] and by Œrsted, in Denmark, a few years later. The genius of Forbes, combined with his extensive knowledge of botany, invertebrate zoology, and geology, enabled him to do more than any of his compeers in bringing the importance of distribution in depth into notice; and his researches in the Ægean Sea, and still more his remarkable paper "On the Geological Relations of the Existing Fauna and Flora of the British Isles," published in 1846, in the first volume of the "Memoirs of the Geological Survey of Great Britain," attracted universal attention.

On the coasts of the British Islands, Forbes distinguishes four zones or regions, the Littoral (between tide-marks), the Laminarian (between low-water mark and 15 fathoms), the Coralline (from 15 to 50 fathoms), and the Deep sea or Coral region (from 50 fathoms to beyond 100 fathoms). But, in the deeper waters of the Ægean Sea, between the shore and a depth of 300 fathoms, Forbes was able to make out

[1] "Enfin plus bas encore, c'est-à-dire alors loin des côtes, le fond des eaux ne paraît plus être habité, du moins dans nos mers, par aucun de ces animaux" (l. c., tome i., p. 237). The "ces animaux" leaves the meaning of the authors doubtful.

[2] In the paper in the "Memoirs of the Survey" cited farther on, Forbes writes:

"In an essay 'On the Association of Mollusca on the British Coasts, considered with reference to Pleistocene Geology,' printed in the *Edinburgh Academic Annual* for 1840, I described the mollusca, as distributed on our shores and seas, in four great zones or regions, usually denominated 'The Littoral Zone,' 'The region of Laminariæ,' 'The region of Corallines,' and 'The region of Corals.' An extensive series of researches, chiefly conducted by the members of the committee appointed by the British Association to investigate the marine geology of Britain by means of the dredge, have not invalidated this classification, and the researches of Prof. Lovén, in the Norwegian and Lapland Seas, have borne out their correctness. The first two of the regions above mentioned had been previously noticed by Lamouroux, in his account of the distribution (vertically) of sea-weeds, by Audouin and Milne Edwards in their 'Observations on the Natural History of the Coast of France,' and by Sars in the preface to his 'Beskrivelser og Jagttagelser.'"

no fewer than eight zones of life, in the course of which the number and variety of forms gradually diminished; until, beyond 300 fathoms, life disappeared altogther. Hence it appeared as if descent in the sea had much the same effect on life as ascent on land. Recent investigations appear to show that Forbes was right enough in his classification of the facts of distribution in depth as they are to be observed in the Ægean; and though, at the time he wrote, one or two observations were extant which might have warned him not to generalize too extensively from his Ægean experience, his own dredging-work was so much more extensive and systematic than that of any other naturalist, that it is not wonderful he should have felt justified in building upon it. Nevertheless, so far as the limit of the range of life in depth goes, Forbes's conclusion has been completely negatived, and the greatest depths yet attained show not even an approach to a "zero of life:"

"During the several cruises of H. M. ships Lightning and Porcupine in the years 1868, 1869, and 1870," says Dr. Wyville Thomson, "fifty-seven hauls of the dredge were taken in the Atlantic at depths beyond 500 fathoms, and sixteen at depths beyond 1,000 fathoms, and, in all cases, life was abundant. In 1869 we took two casts in depths greater than 2,000 fathoms. In both of these life was abundant; and with the deepest cast, 2,435 fathoms, off the mouth of the Bay of Biscay, we took living, well-marked, and characteristic examples of all the five invertebrate sub-kingdoms. And thus the question of the existence of abundant animal life at the bottom of the sea has been finally settled and for all depths, for there is no reason to suppose that the depth anywhere exceeds between three and four thousand fathoms; and, if there be nothing in the conditions of a depth of 2,500 fathoms to prevent the full development of a varied Fauna, it is impossible to suppose that even an additional thousand fathoms would make any great difference."[1]

As Dr. Wyville Thomson's recent letter, cited above, shows, the use of the trawl, at great depths, has brought to light a still greater diversity of life. Fishes came up from a depth of 600 to more than 1,000 fathoms, all "in a peculiar condition from the expansion of the air contained in their bodies. On this relief from the extreme pressure, their eyes, especially, had a singular appearance, protruding like great globes from their heads." Bivalve and univalve mollusca seem to be rare at the greatest depths; but star-fishes, sea-urchins, and other echinoderms, zoophytes, sponges, and protozoa, abound.

It is obvious that the Challenger has the privilege of opening a new chapter in the history of the living world. She cannot send down her dredges and her trawls into these virgin depths of the great ocean

[1] "The Depths of the Sea," p. 30. Results of a similar kind, obtained by previous observers, are stated at length in the sixth chapter, pp. 267–280. The dredgings carried out by Count Pourtales, under the authority of Prof. Peirce, the Superintendent of the United States Coast Survey, in the years 1867, 1868, and 1869, are particularly noteworthy, and it is probably not too much to say, in the words of Prof. Agassiz, "that we owe to the coast survey the first broad and comprehensive basis for an exploration of the sea-bottom on a large scale, opening a new era in zoological and geological research."

without bringing up a discovery. Even though the thing itself may be neither "rich nor rare," the fact that it came from that depth, in that particular latitude and longitude, will be a new fact in distribution, and, as such, have a certain importance.

But it may be confidently assumed that the things brought up will very frequently be zoological novelties; or, better still, zoological antiquities, which in the tranquil and little-changed depths of the ocean have escaped the causes of destruction at work in the shallows, and represent the predominant population of a past age.

It has been seen that Audouin and Milne Edwards foresaw the general influence of the study of distribution in depth upon the interpretation of geological phenomena. Forbes connected the two orders of inquiry still more closely; and, in the thoughtful essay "On the Connection between the Distribution of the Existing Fauna and Flora of the British Isles, and the Geological Changes which have affected their Area, especially during the Epoch of the Northern Drift," to which reference has already been made, he put forth a most pregnant suggestion.

In certain parts of the sea-bottom in the immediate vicinity of the British Islands, as in the Clyde district, among the Hebrides, in the Moray Firth, and in the German Ocean, there are depressed areæ, forming a kind of submarine valleys, the centres of which are from 80 to 100 fathoms, or more, deep. These depressions are inhabited by assemblages of marine animals, which differ from those found over the adjacent and shallower region, and resemble those which are met with much farther north, on the Norwegian coast. Forbes called these Scandinavian detachments "northern outliers."

How did these isolated patches of a northern population get into these deep places? To explain the mystery, Forbes called to mind the fact that, in the epoch which immediately preceded the present, the climate was much colder (whence the name of "glacial epoch" applied to it); and that the shells which are found fossil, or sub-fossil, in deposits of that age are precisely such as are now to be met with only in the Scandinavian or still more arctic regions. Undoubtedly, during the glacial epoch, the general population of our seas had, universally, the northern aspect which is now presented only by the "northern outliers," just as the vegetation of the land, down to the sea-level, had the northern character which is, at present, exhibited only by the plants which live on the tops of our mountains. But, as the glacial epoch passed away, and the present climatal conditions were developed, the northern plants were able to maintain themselves only on the bleak heights, on which southern forms could not compete with them. And, in like manner, Forbes suggested that, after the glacial epoch, the northern animals then inhabiting the sea became restricted to the deeps in which they could hold their own against invaders from the south, better fitted than they to flourish in the warmer waters of the

shallows. Thus depth in the sea corresponded, in its effect upon distribution, to height on the land.

The same idea is applied to the explanation of a similar anomaly in the Fauna of the Ægean:

"In the deepest of the regions of depth of the Ægean, the representation of a northern Fauna is maintained, partly by identical and partly by representative forms. . . . The presence of the latter is essentially due to the law (of representation of parallels of latitude by zones of depth), while that of the former species depended on their transmission from their parent seas during a former epoch and subsequent isolation. That epoch was doubtless the newer Pliocene or Glacial Era, when the *Mya truncata* and other northern forms now extinct in the Mediterranean, and found fossil in the Sicilian tertiaries, ranged into that sea. The changes which there destroyed the *shallow-water* glacial forms, did not affect those living in the depths, and which still survive." [1]

The conception that the inhabitants of local depressions of the sea-bottom might be a remnant of the ancient population of the area, which had held their own in these deep fastnesses against an invading Fauna, as Britons and Gaels have held out in Wales and in Scotland against encroaching Teutons, thus broached by Forbes, received a wider application than Forbes had dreamed of when the sounding machine first brought up specimens of the mud of the deep sea. As I have pointed out elsewhere,[2] it at once became obvious that the calcareous, sticky mud of the Atlantic was made up, in the main, of shells of *Globigerina* and other *Foraminifera*, identical with those of which the true chalk is composed, and the identity extended even to the presence of those singular bodies, the coccoliths and coccospheres, the true nature of which is not yet made out. Here, then, were organisms, as old as the Cretaceous epoch, still alive, and doing their work of rock-making at the bottom of existing seas. What if *Globigerina* and the coccoliths should not be the only survivors of a world passed away, which are hidden beneath three miles of salt-water? The letter which Dr. Wyville Thomson wrote to Dr. Carpenter in May, 1868, out of which all these expeditions have grown, shows that this query had become a practical problem in Dr. Thomson's mind at that time; and the desirableness of solving the problem is put in the foreground of his reasons for urging the government to undertake the work of exploration:

"Two years ago, M. Sars, Swedish Government Inspector of Fisheries, had an opportunity, in his official capacity, of dredging off the Loffoden Islands at a depth of 300 fathoms. I visited Norway shortly after his return, and had an opportunity of studying with his father, Prof. Sars, some of his results. Animal forms were *abundant;* many of them were new to science; and among them was one of surpassing interest, the small crinoid, of which you have a specimen, and which we at once recognized as a degraded type of the

[1] "Memoirs of the Geological Survey of Great Britain," vol. i., p. 390.

[2] "Lay Sermons," etc., "On a Piece of Chalk."

Apiocrinidæ, an order hitherto regarded as extinct, which attained its maximum in the Pear Encrinites of the Jurassic period, and whose latest representative hitherto known was the *Bourguettocrinus* of the chalk. Some years previously, Mr. Absjörnsen, dredging in 200 fathoms in the Hardangerfjord, procured several examples of a star-fish (*Brisinga*), which seems to find its nearest ally in the fossil genus *Protaster*. These observations place it beyond a doubt that animal life is abundant in the ocean at depths varying from 200 to 300 fathoms, that the forms at these great depths differ greatly from those met with in ordinary dredgings, and that, at all events, in some cases, these animals are closely allied to, and would seem to be directly descended from, the Fauna of the early tertiaries.

"I think the latter result might almost have been anticipated; and, probably, further investigation will largely add to this class of data, and will give us an opportunity of testing our determinations of the zoological position of some fossil types by an examination of the soft parts of their recent representatives. The main cause of the destruction, the migration, and the extreme modification of animal types, appears to be change of climate, chiefly depending upon oscillations of the earth's crust. These oscillations do not appear to have ranged, in the northern portion of the Northern Hemisphere, much beyond 1,000 feet since the commencement of the Tertiary epoch. The temperature of deep waters seems to be constant for all latitudes at 39°, so that an immense area of the North Atlantic must have its conditions unaffected by tertiary or post-tertiary oscillations." [1]

As we shall see, the assumption that the temperature of the deep sea is everywhere 39° Fahr. (4° Cent.) is an error, which Dr. Wyville Thomson adopted from eminent physical writers; but the general justice of the reasoning is not affected by this circumstance, and Dr. Thomson's expectation has been, to some extent, already verified. Thus, besides *Globigerina*, there are eighteen species of deep-sea *Foraminifera* identical with species found in the chalk.

Embedded in the chalky mud of the deep sea, in many localities, are innumerable cup-shaped sponges, provided with six-rayed silicious spicula, so disposed that the wall of the cup is formed of a lace-work of flinty thread. Not less abundant, in some parts of the chalk formation, are the fossils known as *Ventriculites*, well described by Dr. Thomson as "elegant vases or cups, with branching, root-like bases, or groups of regularly or irregularly spreading tubes delicately fretted on the surface with an impressed net-work like the finest lace;" and, he adds: "When we compare such recent forms as *Aphrocallistes*, *Iphiteon*, *Holtenia*, and *Askonema*, with certain series of the chalk *Ventriculites*, there cannot be the slightest doubt that they belong to the same family—in some cases to very nearly-allied genera." [2]

Prof. Duncan finds "several corals from the coast of Portugal more nearly allied to chalk-forms than to any others."

The stalked crinoids, or feather-stars, so abundant in ancient times, are now exclusively confined to the deep sea, and the late explorations

[1] "The Depths of the Sea," pp. 51, 52. [2] Ibid., p. 484.

have yielded forms of old affinity, the existence of which has hitherto been unsuspected. The general character of the group of star-fishes embedded in the white chalk is almost the same as in the modern Fauna of the deep Atlantic. The sea-urchins of the deep sea, while none of them are specifically identical with any chalk-form, belong to the same general groups, and some closely approach extinct cretaceous genera.

Taking these facts in conjunction with the positive evidence of the existence, during the Cretaceous epoch, of a deep ocean where now lies the dry land of Central and Southern Europe, Northern Africa, and Western and Southern Asia; and of the gradual diminution of this ocean during the older Tertiary epoch, until it is represented at the present day by such teacupfuls as the Caspian, the Black Sea, and the Mediterranean; the supposition of Dr. Thomson and Dr. Carpenter that what is now the deep Atlantic was the deep Atlantic (though merged in a vast easterly extension) in the Cretaceous epoch, and that the *Globigerina* mud has been accumulating there from that time to this, seems to me to have a great degree of probability. And I agree with Dr. Wyville Thomson against Sir Charles Lyell (it takes two of us to have any chance against his authority) in demurring to the assertion that "to talk of chalk having been uninterruptedly formed in the Atlantic is as inadmissible in a geographical as in a geological sense."

If the word "chalk" is to be used as a stratigraphical term and restricted to *Globigerina* mud deposited during the Cretaceous epoch, of course it is improper to call the precisely similar mud of more recent date chalk. If, on the other hand, it is to be used as a mineralogical term, I do not see how the modern and the ancient chalks are to be separated; and, looking at the matter geographically, I see no reason to doubt that a boring-rod driven from the surface of the mud which forms the floor of the mid-Atlantic would pass through one continuous mass of *Globigerina* mud, first of modern, then of tertiary, and then of mesozoic date; the "chalks" of different depths and ages being distinguished merely by the different forms of other organisms associated with the *Globigerinæ*.

On the other hand, I think it must be admitted that a belief in the continuity of the modern with the ancient chalk has nothing to do with the proposition that we can, in any sense whatever, be said to be still living in the Cretaceous epoch. When the Challenger's trawl brings up an Ichthyosaurus, along with a few living specimens of Belemnites and Turrilites, it may be admitted that she has come upon a cretaceous "outlier;" but a geological period is characterized not only by the presence of those creatures which lived in it, but by the absence of those which have only come into existence later; and, however large a proportion of true cretaceous forms may be discovered in the deep sea, the modern types associated with them must be abolished

before the Fauna, as a whole, could, with any propriety, be termed Cretaceous.

I have now indicated some of the chief lines of Biological inquiry, in which the Challenger has special opportunities for doing good service, and in following which she will be carrying out the work already commenced by the Lightning and Porcupine in their cruises of 1868 and subsequent years.

But biology, in the long-run, rests upon physics, and the first condition for arriving at a sound theory of distribution in the deep sea is, the precise ascertainment of the conditions of life; or, in other words, a full knowledge of all those phenomena which are embraced under the head of the "Physical Geography of the Ocean."

Excellent work has already been done in this direction, chiefly under the superintendence of Dr. Carpenter, by the Lightning and the Porcupine,[1] and some data of fundamental importance to the physical geography of the sea have been fixed beyond a doubt.

Thus, though it is true that sea-water steadily contracts as it cools down to its freezing-point, instead of expanding before it reaches its freezing-point as fresh water does, the truth has been steadily ignored by even the highest authorities in physical geography, and the erroneous conclusions deduced from their erroneous premises have been widely accepted as if they were ascertained facts. Of course, if sea-water, like fresh water, were heaviest at a temperature of 39° Fahr., and got lighter as it approached 32°, the water of the bottom of the deep sea could not be colder than 39°. But one of the first results of the careful ascertainment of the temperature at different depths, by means of thermometers specially contrived for the avoidance of the errors produced by pressure, was the proof that, below 1,000 fathoms in the Atlantic, down to the greatest depths yet sounded, the water has a temperature yet lower than 38° Fahr., whatever be the temperature of the water at the surface. And that this low temperature of the deepest water is probably the universal rule for the depths of the open ocean is shown, among others, by Captain Chimmo's recent observations in the Indian Ocean, between Ceylon and Sumatra, where, the surface-water ranging from 85° to 81° Fahr., the temperature at the bottom, at a depth of 2,270 to 2,656 fathoms, was only from 34° to 32° Fahr.

As the mean temperature of the superficial layer of the crust of the earth may be taken at about 50° Fahr., it follows that the bottom layer of the deep sea in temperate and hot latitudes is, on the average, much colder than either of the bodies with which it is in contact; for the temperature of the earth is constant, while that of the air rarely falls so low as that of the bottom water in the latitudes in question; and, even when it does, has time to affect only a compara-

[1] "Proceedings of the Royal Society," 1870 and 1872.

tively thin stratum of the surface-water before the return of warm weather.

How does this apparently anomalous state of things come about? If we suppose the globe to be covered with a universal ocean, it can hardly be doubted that the cold of the regions toward the poles must tend to cause the superficial water of those regions to contract and become specifically heavier. Under these circumstances, it would have no alternative but to descend and spread over the sea-bottom, while its place would be taken by warmer water drawn from the adjacent regions. Thus, deep, cold, polar-equatorial currents, and superficial, warmer, equatorial-polar currents, would be set up; and, as the former would have a less velocity of rotation from west to east than the regions toward which they travel, they would not be due southerly or northerly currents, but southwesterly in the Northern Hemisphere, and northwesterly in the Southern; while, by a parity of reasoning, the equatorial-polar warm currents would be northeasterly in the Northern Hemisphere, and southeasterly in the Southern. Hence, as a northeasterly current has the same direction as a southwesterly wind, the direction of the northern equatorial-polar current in the extratropical part of its course would pretty nearly coincide with that of the anti-trade winds. The freezing of the surface of the polar sea would not interfere with the movement thus set up. For, however bad a conductor of heat ice may be, the unfrozen sea-water immediately in contact with the under surface of the ice must needs be colder than that farther off; and hence will constantly tend to descend through the subjacent warmer water.

In this way it would seem inevitable that the surface-waters of the northern and southern frigid zones must, sooner or later, find their way to the bottom of the rest of the ocean; and there accumulate to a thickness dependent on the rate at which they absorb heat from the crust of the earth below, and from the surface-water above.

If this hypothesis be correct, it follows that, if any part of the ocean in warm latitudes is shut off from the influence of the cold polar underflow, the temperature of its deeps should be less cold than the temperature of corresponding depths in the open sea. Now, in the Mediterranean, Nature offers a remarkable experimental proof of just the kind needed. It is a land-locked sea which runs nearly east and west, between the twenty-ninth and forty-fifth parallels of north latitude. Roughly speaking, the average temperature of the air over it is 75° Fahr. in July, and 48° in January.

This great expanse of water is divided by the peninsula of Italy (including Sicily), continuous with which is a submarine elevation carrying less than 1,200 feet of water, which extends from Sicily to Cape Bon in Africa, into two great pools—an eastern and a western. The eastern pool rapidly deepens to more than 12,000 feet, and sends off to the north its comparatively shallow branches, the Adriatic and the

Ægean Seas. The western pool is less deep, though it reaches some 10,000 feet. And, just as the western end of the eastern pool communicates by a shallow passage, not a sixth of its greatest depth, with the western pool, so the western pool is separated from the Atlantic by a ridge which runs between Capes Trafalgar and Spartel, on which there is hardly 1,000 feet of water. All the water of the Mediterranean which lies deeper than about 150 fathoms, therefore, is shut off from that of the Atlantic, and there is no communication between the cold layer of the Atlantic (below 1,000 fathoms) and the Mediterranean. Under these circumstances, what is the temperature of the Mediterranean? Everywhere below 600 feet it is about 55° Fahr.; and consequently, at its greatest depths, it is some 20° warmer than the corresponding depths of the Atlantic.

It seems extremely difficult to account for this difference in any other way than by adopting the view so strongly and ably advocated by Dr. Carpenter, that, in the existing distribution of land and water, such a circulation of the water of the ocean does actually occur, as theoretically must occur, in the universal ocean, with which we started.

It is quite another question, however, whether this theoretic circulation, true cause as it may be, is competent to give rise to such movements of sea-water, in mass, as those currents, which have commonly been regarded as northerly extensions of the Gulf Stream. I shall not venture to touch upon this complicated problem; but I may take occasion to remark that the cause of a much simpler phenomenon—the stream of Atlantic water which sets through the Straits of Gibraltar, eastward, at the rate of two or three miles an hour or more, does not seem to be so clearly made out as is desirable.

The facts appear to be that the water of the Mediterranean is very slightly denser than that of the Atlantic (1.0278 to 1.0265), and that the deep water of the Mediterranean is slightly denser than that of the surface; while the deep water of the Atlantic is, if any thing, lighter than that of the surface. Moreover, while a rapid superficial current is setting in (always, save in exceptionally violent easterly winds) through the Straits of Gibraltar, from the Atlantic to the Mediterranean, a deep under-current (together with variable side-currents) is setting out through the Straits, from the Mediterranean to the Atlantic.

Dr. Carpenter adopts, without hesitation, the view that the cause of this indraught of Atlantic water is to be sought in the much more rapid evaporation which takes place from the surface of the Mediterranean than from that of the Atlantic; and thus, by lowering the level of the former, gives rise to an indraught from the latter.

But is there any sound foundation for the three assumptions involved here: Firstly, that the evaporation from the Mediterranean, as a whole, is much greater than that from the Atlantic under corresponding parallels; secondly, that the rainfall over the Mediterra-

nean makes up for evaporation less than it does over the Atlantic; and thirdly, supposing these two questions answered affirmatively: Are not these sources of loss in the Mediterranean fully covered by the prodigious quantity of fresh water which is poured into it by great rivers and submarine springs? Consider that the water of the Ebro, the Rhine, the Po, the Danube, the Don, the Dnieper, and the Nile, all flow directly or indirectly into the Mediterranean; that the volume of fresh water which they pour into it is so enormous that fresh water may sometimes be baled up from the surface of the sea off the Delta of the Nile, while the land is not yet in sight; that the water of the Black Sea is half fresh, and that a current of three or four miles an hour constantly streams from it Mediterraneanward through the Bosporus; consider, in addition, that no fewer than ten submarine springs of fresh water are known to burst up in the Mediterranean, some of them so large that Admiral Smyth calls them "subterranean rivers of amazing volume and force;" and it would seem, on the face of the matter, that the sun must have enough to do to keep the level of the Mediterranean down; and that, possibly, we may have to seek for the cause of the small superiority in saline contents of the Mediterranean water in some condition other than solar evaporation.

Again, if the Gibraltar indraught is the effect of evaporation, why does it go on in winter as well as in summer?

All these are questions more easily asked than answered; but they must be answered before we can accept the Gibraltar stream as an example of a current produced by indraught, with any comfort.

The Mediterranean is not included in the Challenger's route, but she will visit one of the most promising and little explored of hydrographical regions—the North Pacific, between Polynesia and the Asiatic and American shores; and, doubtless, the store of observations upon the currents of this region, which she will accumulate, when compared with what we know of the North Atlantic, will throw a powerful light upon the present obscurity of the Gulf Stream problem.—*Contemporary Review.*

CONDENSED MILK IN ENGLAND.

By Dr. EDWARD LANKESTER.

THE importance of milk as an article of diet is so great that anything offered as a substitute for it, or that renders it more available as food, demands attention. The composition of cow's milk is so nearly like woman's milk that the addition of a little water and sugar may be said to convert the one into the other; hence the practice of giving cow's milk to young children, and making it a substantial

article of their diet long after they have cut their teeth and are able to masticate bread and meat. No inconsiderable quantity of milk is also consumed by adults, and its nutritive effect is not exceeded by any article of diet, as it contains all the constituents that are necessary to the perfect nutrition of the human body.

There are, however, several drawbacks in the use of cow's milk which diminish its utility, limit its use, and sometimes render it dangerous. One of the great drawbacks in milk is its liability to decomposition. The sugar it contains becomes acid, the caseine separates in the form of curd, and a fermentation ensues which renders it unpleasant and sometimes even dangerous as an article of diet. The latter effect is seen more particularly in young children. During the summer months they suffer extensively from diarrhœa, and there is little doubt that this is largely due to the acidity of the milk which is given to them. Milk bought in the morning in London is frequently unfit to be used in the evening for the diet of infants. These changes in milk are hastened by the present system of bringing milk to London from a distance in cans, by which means it is shaken, and its tendency to change hastened.

Another drawback in the use of milk is its liability to adulteration. Unfortunately, the agent by which milk is adulterated is easily accessible, and can be detected with great difficulty. We cannot instruct cooks and poor people in the use of lactometers and hydrometers by which the learned test milk; moreover, the natural liability of milk to vary is very great. Thus the quantity of cream in milk received by the Aylesbury Condensed Milk Company varies from 9 to 17 per cent. Dr. Hassell states that the cream given by the milk of a cow, the milk of which he personally inspected, was but 4½ per cent. Although, then, all milk containing less than 9 per cent. of cream may be suspected of adulteration, yet it may happen that a milk containing but 4½ per cent. may be really not adulterated with water at all.

This varying quantity of cream also shows that, even when milk is not adulterated, it is liable to great variations in the quantity of cream which may be taken as the measure of its usefulness as an article of food.

Many attempts have been made to overcome these objections to the use of milk, and from time to time preparations of it have been sold by which freedom from acidity and adulteration is secured. The most available of these preparations have been those that submitted the milk to a process of evaporation by which more or less of the water naturally contained in milk is got rid of. By these processes the nutritive constituents of the milk are retained; the preparation keeps for some time, is easily conveyed from place to place, and, by the addition of water, milk, so to speak, is readily manufactured. None of these preparations, however, seemed to succeed till a process for making what is called "condensed milk" was introduced. Whether

America or Europe has the honor of the invention we need not dispute here. It is now made in this country by thousands of gallons daily, and its manufacture may be witnessed on a large scale at Aylesbury.

Although the process of evaporating milk may be regarded as an exceedingly simple one, the attempt to carry it out at Aylesbury on a large scale has developed a complicated machinery in which steam-power is extensively used; 200 persons are employed, and the milk of 1,200 cows, each yielding 14 quarts, is daily evaporated. The milk used is brought from farms in the neighborhood in ordinary tin cans. Each can before it is sent to the factory is carefully tested by the taste and smell and the lactometer. Any doubtful specimens are set aside for reëxamination or rejection. The milk is then passed into a vacuum pan, and the vapor thus produced is carried off and condensed and thrown away. When the milk has acquired a proper consistence, it is mixed with sugar. This addition of sugar is the distinguishing feature of the condensed-milk process. After this the milk is still further condensed till it reaches the required consistence, and is run off into the little tin cans which are so well known. The whole of these operations are carried out with a regard for cleanliness which would look almost fastidious if it were not known that a single particle of decomposing milk allowed to get into the receiving-pans might destroy the whole mass. Every can is returned thoroughly cleansed to the farmer who sends it, having been first submitted to hot water, then to a jet of steam, and then rinsed out by a jet of cold water.

The condensed milk thus prepared is of a semi-liquid consistence, and can be taken out of a jar with a spoon. Several analyses of this milk have been made. The late Baron Liebig found that it contained—

Water	22.44
Solids	77.56
	100.00

The *Lancet* has more recently published the following analysis:

Moisture	25.10
Butter	11.73
Caseine	15.17
Milk-sugar	16.24
Cane-sugar	29.46
Ash	2.30
	100.00

From these analyses it will at once be seen that the only perceptible difference between condensed milk and ordinary milk is, that the former contains more sugar and less water than the latter. Both these things are necessary for attaining the objects for which condensed milk is manufactured. The diminution of the bulk of the water from 87 per cent. in ordinary milk to 25 per cent. in the condensed secures diminution of the bulk of the milk, and thus renders transportation

comparatively easy. The condensed milk is easily converted to the condition of ordinary milk by the addition of either cold or hot water. The addition of the sugar is found to be necessary, in order to enable the other constituents to resist decomposition. Milk will keep any length of time when entirely desiccated, but, by the process of drying entirely, the milk loses its flavor and many of its properties. The semi-liquid condition of condensed milk prevents these changes, but in this state it is liable to decompose; hence the necessity of additional sugar.

The question arises as to whether this added sugar in any way interferes with the quality of the milk in its relation to the diet of infants or invalids. In comparing human milk with cow's milk, we find that the latter contains more caseine and less sugar than the former. Hence, when given to children, it is customary to add a little water and a little sugar to make it like mother's milk. This object is really effected by the addition of cane-sugar to the condensed milk, and it may, therefore, be unhesitatingly employed in the nursery as a substitute for ordinary cow's milk.

After a personal inspection of the Aylesbury manufactory, and a full consideration of the whole subject, we are quite prepared to say that, where good fresh cow's milk is unattainable, as it is almost practically so in our large towns, there is no substitute for it equal to condensed milk. Nor is this a matter of theory; hundreds of gallons are being used every day in London, and most of it under the direction of experienced medical men. One medical man assures us that he has a healthy, fine-grown child of ten months that has never taken any thing but condensed milk. As the diet of invalids, it may in some cases require watching when the action of sugar is injurious to the system; but in these cases milk should be altogether interdicted.

It is to be hoped that no disadvantage in the use of this agent has been overlooked, as the advantages of its use are so many and so obvious. It presents a pure form of milk in a condition in which it may be kept for any length of time, and is not injured by removal. It is always at hand night and day, and, by the addition of cold or hot water, can be converted into nutritious and wholesome food.—*Nature.*

LOWLY VEGETABLE FORMS.

By Rev. HUGH MACMILLAN.

LIFE is everywhere. "Nature *lives*," says Lewes; "every pore is bursting with life; every death is only a new birth; every grave a cradle." "The earth-dust of the universe," says Jean Paul, "is inspired by the breath of the great God. The world is brimming with life; every leaf on every tree is a land of spirits." The tendency

to vegetate is a ceaseless power. It has been in operation from the earliest ages of the earth, ever since living beings were capable of existing upon its surface; and so active in the past history of the globe has been this tendency, that most of the superficial rocks of the earth's crust are composed of the remains of plants. It operates with undiminished and tireless energy still. Vegetation takes place upon almost every substance; upon the bark of trees, upon naked rocks, upon the roofs of houses, upon dead and living animal substances, upon glass when not constantly kept clean, and even on iron which had been subjected to a red heat a short time before. Zoologists tell us, when speaking of animalcules, that not a drop of stagnant water, not a speck of vegetable or animal tissue, not a portion of organic matter, but has its own appropriate inhabitants. The same may be said of plants; for we can hardly point to a single portion of the earth's surface which is not tenanted by some vegetable form whose structure is wonderfully adapted to its situation and requirements. Even in the hottest thermal springs, and on the eternal snows of the arctic regions, peculiar forms of vegetation have been found. From the deepest recesses of the earth to which the air can penetrate, to the summits of the loftiest mountains; from the almost unfathomable depths of the ocean to the highest clouds; from pole to pole, the vast stratum of vegetable life extends; while it ranges from a temperature of 35° to 135° Fahr., a range embracing almost every variety of conditions and circumstances.

The most cursory and superficial glance will recognize in every scene a class of plants whose singular appearances, habits, and modes of growth, so prominently distinguish them from the trees and flowers around, that they might seem hardly entitled to a place in the vegetable kingdom at all. On walls by the wayside, on rocks on the hills, and on trees in the woods, we see tiny green tufts and gray stains, or party-colored rosettes spreading themselves, easily dried by the heat of the sun, and easily revived by the rain. In almost every stream, lake, ditch, or any collection of standing or moving water, we observe a green, slimy matter, forming a scum on the surface, or floating in long filaments in the depths. On almost every fallen leaf and decayed branch, fleshy, gelatinous bodies of different forms and sizes meet our eye. Sometimes all these different objects appear growing on the same substance. If we examine a fallen, partially-decayed twig, half-buried in the earth in a wood, we may find it completely covered with various representatives of these different vegetable growths; and nothing surely can give us a more striking or convincing proof of the universal diffusion of life. All these different plants belong to the second great division of the vegetable kingdom, to which the name of *Cryptogamia* has been given, on account of the absence, in all the members, of those prominent organs which are essential to the production of perfect seed. They are propagated by little embryo plants

called spores, or sporules, generally invisible to the naked eye, and differing from true seeds in germinating from any part of their surface instead of from two invariable points. Besides this grand distinguishing mark, they possess several other peculiar qualities in common. They consist of cells only, and hence are often called cellular plants, in contradistinction to those plants which are possessed of fibres and woody tissue. Their development is also superficial, growth taking place from the various terminal points; and hence they are called acrogens and thallogens, to distinguish them from monocotyledonous and dicotyledonous plants. Popularly, they are known as mosses, lichens, algæ, and fungi. They open up a vast field of physiological research. They constitute a microcosm, a strange minute world underlying this great world of sense and sight, which, though unseen and unheeded by man, is yet ever in full and active operation around us. It is pleasant to turn aside for a while from the busy human world, with its ceaseless anxieties, sorrows, and labors, to avert our gaze from the splendors of forest and garden, from the visible display of green foliage and rainbow-colored blossoms around us, and contemplate the silent and wonderful economy of that other world of minute or invisible vegetation with which we are so mysteriously related, though we know it not. There is something exceedingly interesting in tracing Nature to her ultimate and simplest forms. The mind of man has a natural craving for the infinite. It delights to speculate either on the vast or the minute; and we are not surprised at the paradoxical remark of Linnæus, that Nature appeared to him greatest in her least productions.

These plants once occupied the foremost position in the economy of Nature. Like many decayed families whose founders were kings and mighty heroes, but whose descendants are beggars, they were once the aristocracy of the vegetable kingdom, though now reduced to the lowest ranks, and considered the *canaille* of vegetation. Geology reveals to us the extraordinary fact that one whole volume of the earth's stony book is filled almost exclusively with their history. Life may have been ushered upon our globe through oceans of the lowest types of *Confervæ*, long previous to the deposit of the oldest palæozoic rocks as known to us; and for myriads of ages these extremely simple and minute plants may have represented the only idea of life on earth. But, passing from conjecture to the domain of established truth, we know of a certainty that, at least throughout the vast periods of the Carboniferous era, ferns, mosses, and still humbler plants, occupied the throne of the vegetable kingdom, and, by their countless numbers, their huge dimensions, and rank luxuriance, covered the whole earth with a closely-woven mantle of dark-green verdure—from Melville Island in the extreme north, to the islands of the Antarctic Ocean in the extreme south. The relics of these immense primeval forests, reduced to a carbonaceous or bituminous condition by the

secret resources of Nature's laboratory, amid so many convulsions of the globe, are now buried deep in the bowels of the earth, packed into solid sandstone cases, and under huge shady covers, and stored up in the smallest compass by the mighty pressure of ponderous rock-presses, constituting the chief source of our domestic comfort, and of nearly all our commercial greatness. A coal-bed is, in fact, a *hortus siccus* of extinct cryptogamic vegetation, bringing before the imagination a vista of the ancient world, with which no arrangement of landscape or combination of scenery can now be compared; and, gazing upon its dusky contents, our minds are baffled in aiming to comprehend the bulk of original material, the seasons of successive growth, and the immeasurable years or ages which passed while decay, and maceration, and chemical changes, prepared the fallen vegetation for fuel. If the specimens of plants, thus strangely preserved, teach us one truth more than another, it is this, that size and development are terms of no meaning when applied to a low or a high type of organization. The *Cryptogamia* of the Old World, the earliest planting in the new-formed soil, are in bulk, as well as in elegance and beauty of form, unrivalled by the finest specimens of the modern forest. The little and the great, the recent and the extinct, were equally the objects of Nature's care, and were all modelled with a skill and finish that left nothing to be added.

And as in early geological epochs they occupied so conspicuous a position, so now in the annals of physical geography they are entitled to a prominent place. With the exception of the grasses—Nature's special favorites—they are the most abundant of all plants, possessing inconceivable myriads of individual representatives in every part of the globe, from which unfavorable conditions exclude all other vegetation; and thus they contribute, far more than we are apt from a superficial observation to imagine, to the picturesque and romantic appearances exhibited by scenery, and to the formation of that richly-woven and beautifully-decorated robe of vegetation which conceals the ghastly skeleton of the earth, and hides from our view the rugged outlines and primitive features of Nature. They are the first objects that clothe the naked rocks which rise above the surface of the ocean; and they are the last traces of vegetation which disappear under degrees of heat and cold fatal to all life. Their structure is so singularly varied and plastic, that they are adapted to every possible situation. In every country they form an important element in the number of plants, the proportion to flowering plants decreasing from and increasing toward the poles. Taking them as a whole, and in regard to their size, they occupy a larger area of the earth's surface than any other kind of vegetation. There are immense forests of trees here and there in different countries, realizing Cowper's wish for "a boundless contiguity of shade;" there are vast colonies of flowering plants; but the range of the most ubiquitous tree or flower is vastly inferior to that of

some of the humblest lichens and mosses. Although these plants occupy but a very subsidiary and unimportant position among the vegetation which surrounds us in our daily walks, and are concealed in isolated patches in the woods and fields by the luxuriance of higher and more conspicuous plants, yet they constitute the sole vegetation of very extensive regions of the earth's surface. Every part of the globe, within a thousand feet of the line of perpetual snow, is redeemed from utter desolation by these plants alone. Above the valleys and the lower slopes which form the step of transition from plain to mountain—inhabited by prosperous and civilized nations—is the domain of mist and mystery, the region of storm—a world which is not of this world, where God and Nature are all in all, and man is nothing; and in this unknown region there are immense tracts familiar to the eye of wild bird, to the summer cloud, the stars and meteors of the night—strange to human faces and the sound of human voices, where the lichen and the moss alone luxuriate and carpet the sterile ground. The grandest and sublimest regions of the earth are adorned with garlands of the minutest and humblest plants; they are the tapestry, the highly-wrought carpeting laid down in the vestibules of Nature's palaces. If we look at a map of the world, we see that Europe and Asia are held together as it were by a huge ridge or backbone of mountain-elevation, which, although suffering partial interruption, may be roughly described as continuous from one ocean to another. It begins with the mountains of Biscay in Spain, passes on through the Pyrenees, with a slight interruption, into the Alps, which throw off the important spur or rib of the Apennines; thence it divides into the Balkan and Carpathians. We trace the chain next in the Caucasus and the mountains of Armenia—with the interruption of the Caspian Sea—passing into the Hindoo Coosh and the Himalaya Mountains, whence the chain forks and takes a direction north and south, enclosing like walls the whole delta of China, and thence dips into the eastern ocean. In Africa also, at its widest part, there is a similar backbone, beginning not far from Sierra Leone, and losing itself in the east in the mountains of Abyssinia; while in America the mountain-spine trends north and south from the Hudson's Bay territories, through the Rocky Mountains, uninterruptedly through the Isthmus of Panama, along the Andes to the Straits of Magellan. These vast mountain-systems, with their culminating regions in the Andes, Alps, and Himalayas, and their subsidiary branches or ribs in the Grampians, Dovrefields, Ural, and Atlantic ranges, are clothed on their sides, summits, and elevated plateaus, almost exclusively with cryptogamic vegetation, and enable us to form some conception of the immense altitudinal range of these plants. Then there are whole islands in the Arctic and Antarctic Oceans whose vegetation also is almost entirely cellular. The northern portion of Lapland, the continent of Greenland, the large islands of Spitzbergen, Nova Zembla, and Iceland, the extensive territories

of the Hudson's Bay Company, the enormous tracts of level land which border the Polar Ocean from the North Cape to Behring's Straits, across the north of Europe and Asia, and from Behring's Straits to Greenland, across the north of America, a stretch of many thousands of miles; all these immense areas of the earth's surface—where not a tree, nor a shrub, nor a flower is seen, except the creeping arctic willow and birch, and the stunted moss-like saxifrage and scurvy-grass—are covered with fields of lichens and mosses, far exceeding any thing that can be compared in that respect among phanerogamous plants. Thus, to the rugged magnificence of Alpine scenery, and the dreary isolation and uniformity of the arctic steppes, and the boundless wastes of brown desert and misty moorland, to these great outlets from civilization and the tameness of ordinary life, which allow the soul to expand and go out in sublime imaginings toward the infinity of God, these humble plants form the sole embellishments.

So much for the distribution of these plants on the land; their range in the waters is still more extensive. Lichens and mosses cover the waste surfaces of the earth; diatoms and confervæ are everywhere miraculously abundant in the waters—in rivers and streams, in ditches and ponds, alike under the sunny skies of the south, and in the frozen regions of the north; on the surface of the sea in floating meadows, and in the dark and dismal recesses of the ocean only to be explored by the long line of the sounding-lead. The ocean swarms with innumerable varieties, without their presence being indicated by any discoloration of the fluid. The Arctic and Antarctic Oceans, covering areas larger than the Continents of Europe and Asia, are peopled by myriads of diatoms; various inland seas and lakes are tinged of different hues by their predominance in the waters; while it has been ascertained, from the soundings obtained during the investigations connected with laying the electric telegraph-cable between Ireland and Newfoundland, that the floor of the Atlantic is paved many feet deep with their silicious shields, preserving in all their integrity their wonderful shapes, notwithstanding their extreme delicacy and minuteness, and the enormous pressure of the vast body of water which rests above them. Such is the wide space which these organisms occupy in the fields of Nature—a prominence which is surely sufficient to redeem them from the charge of insignificance. They are inferior in majesty of form to palms and oaks, but in their united influence it is not too extravagant to say that they are not less important than the great forests of the world.

This vast profusion of minute and humble vegetable life serves the obvious purpose of preparing the way for higher orders of vegetation. Nature is incessantly working out vast ends by humble and scarcely recognizable means. The features of the earth are being continually altered by the germination and dispersion of the algæ, mosses, and lichens. Bare and sterile mountains are clothed with verdure; rocks

are mouldering into soil; seas are filling up; rivers and streams are continually shifting their outlines; and lakes are converted into fertile meadows and the sites of luxuriant forests, by means of the vast armies of Nature's pioneers. Hard inorganic matters are reduced to impalpable atoms; waters and gases are decomposed and moulded into new forms and substances having new properties, by vegetable growth. Minute as these plants are, they are intimately related to the giant forms of the universe. It has been observed that as the great whole is indissolubly connected with its minutest parts, so the germination of the minutest lichen and the growth of the simplest moss are directly linked with the grandest astronomical phenomena; nor could the smallest fungus or conferva be annihilated without destroying the equilibrium of the universe. It is with organic Nature as with the body politic or the microcosm of the human frame, if "one member suffer all the members suffer with it," and the loss of one class or order would involve that of another, till all would perish. Our comfort and health, nay our very existence, more or less immediately depend on the useful functions which they perform. Before we can have the wheat which forms our daily bread, or the grass which yields us, through the instrumentality of our herds, our daily supply of animal food, or the cotton and lint which form our clothes, countless generations of lichens and mosses must have been at work preparing a soil for the growth of the plants which produce these useful materials. And as on the dry land, so in the great waters, this wonderful chain of connection exists in all its complexity. Before the reader can peruse these pages by the light of the midnight lamp, or the gay party can indulge their revels under the brilliant glare of spermaceti tapers, myriads of minute diatoms and *Confervæ*, floating in the waters of the sea, must have formed a basis of subsistence for the whales and seals whose oil is employed for these purposes. Man's own structure is nourished and built up by the particles which these active plants have rescued from the mineral kingdom, and which once circulated through their simple cells; and thus the highest and most complex creature, by a vital sympathy and a close physical relation, is connected with the lowest and simplest organism, to teach him humility, and inspire him with a deep interest in all the works of his Maker!

> "Nothing in this world is single;
> All things, by a law divine,
> In one another's being mingle."

It may be asked by a class of individuals, unfortunately too numerous, What is the use of these minute plants? In the business language of the world things are called useful when they promote the profit, convenience, or comfort, of every-day life; and useless when they do not promote, or when they hinder, either of these desired ends. But this definition is extremely partial and one-sided. There are

higher purposes to serve in this world than mere subservience to the physical wants of man. There is a much higher utility than the mere temporary and worldly one. The useful things of external life, indeed, should not be undervalued; they are the first things required, but they are not the sole or the highest things necessary. Man must have food and clothing in order to live; but it must also be remembered that man does not live by bread and the conveniences of external life alone. When any one does live by these alone, he has forfeited his claim to the higher form of life which is his glorious privilege, and by which he is distinguished from the lower animals. Nature throughout her whole wide domains gives no countenance to such a materialistic exclusiveness. She is at once utilitarian and transcendental. Uses and beauties intermingle. All that is useful is around us; but how much more is there besides? There is a strange superfluous glory in the summer air; there is marvellous beauty in the forms and hues of flowers; there is an enchanting sweetness in the song of birds and the murmur of waters; there are a divine grandeur and loveliness in the landscapes of earth and the scenery of the heavens, the changes of the seasons, the dissolving splendors of morning, noon, sunset, and night, utterly incomprehensible upon the theory of Nature's exclusive utilitarianism. "The tree which shades the wayfarer in the noontide heat adorns the landscape; and the flower which gives honey to the bee sheds its perfume on the air. A leaf no less than a flower fulfils the functions of life, ministers to the necessities of man, yet clothes itself, and adorns the earth in tapestries richer than the robes of kings." All things proclaim that the Divine Architect, while amply providing for the physical wants of his creatures, has not forgotten their spiritual necessities and enjoyments; and, having implanted in the human soul a yearning for the beautiful, has surrounded us with a thousand objects by whose charms that yearning may be gratified. And one of the most striking examples of this Divine care is to be seen in the profusion of minute objects spread around us, which apparently have no direct influence at all upon man's physical nature, and have no connection with his corporeal necessities. These objects, subserving no gross utilitarian purpose, are intended to educate man's spiritual faculties by the beauties of form, the wonders of structure, and the adaptations of economy which they display. Their beauty is sufficient reason for their existence, were there no other. When their varied and exquisitely symmetrical forms are presented to the eye under the microscope, a thrill of pleasure is experienced, calm and pure, because free from all taint of passion, and felt all the more intensely because nameless and indefinite. We are brought face to face with perfection in its most wonderful aspect—the perfection of minuteness and detail; with objects which bear most deeply impressed upon them the signet-mark of their Maker; and we observe with speechless admiration that the Divine attention is acuminated and his skill concentrated on these

vital atoms; the last visible organism vanishing from our view with the same Divine glory upon it, as the last star that glimmers out of sight on the remotest verge of space.

These organisms further justify their existence to the utilitarian, inasmuch as their study is well calculated to exercise an educational influence which should not be overlooked or despised. While they try the patience, they exercise the faculties by forcing attention upon details. Their minuteness, their general resemblance to each other, their want in many cases of very prominent or marked characteristics, render it a somewhat difficult task to identify them. Long hours may often be spent in ascertaining the name of a single species, and assigning it its proper place in the tribe to which it belongs. One species may often be confounded with another closely allied, and days and weeks may elapse before the eye and the mind, familiarized with their respective details, can observe the distinctions between them. This difficulty of identification greatly sharpens one's knowledge, induces a habit of paying attention to minutiæ, and creates a power of distinguishing between things that differ slightly, which is exceedingly valuable and important. For the eye and mind thus educated to detect resemblances and differences in objects, which to ordinary observation appear widely dissimilar or precisely the same, there will be abundant scope in the practical details of common every-day life, as well as in the higher walks of literature, science, and art.

The study of these plants has also a tendency to elevate and enlarge our conceptions of Nature; its vastness and complexity, its incommunicable grandeur, its all but infinity, opening before us newer and more striking vistas with every descending step we take. The farther we advance, and the wider our sphere of observation extends, wonder follows on wonder, till our faculties become bewildered, and our intellect falls back on itself in utter hopelessness of arriving at the end. Minute as the objects are in themselves, contact with them cannot fail to excite the mind, to call it forth into full and vigorous exercise, to enlist its sympathies, and to expand its faculties. Many eloquent pages have been written to show this elevating influence upon the mind, of contact with and contemplation of the phenomena of Nature; but it is not the great and sublime objects of Nature alone that produce this effect—the sublimity of mountains, the majesty of rivers, and the repose of forests—the very humblest and simplest objects are calculated to awaken these emotions in a yet higher and purer form. "The microscope," as Mr. Lewes has well observed, "is not the mere extension of a faculty; it is a new sense."

There are also peculiar pleasures connected with the study of these objects. There is, first, the pleasure of novelty and discovery—of exploring a realm where every thing is comparatively new, and every step is delightful; where the forms are unfamiliar, and the modes of life hitherto unimagined. There is, next, the more subtle and refined

pleasure of observing the strange truths which they unfold, the beautiful laws which they reveal, and the resemblances and relations which they display. The false romanticism of vulgar fancy requires something pretentious and unnatural to gratify its taste; but, to the true poetical mind, the humblest moss on the wall, or the green slime that creams on the wayside pool, will suggest trains of pleasing and profitable reflection. He who has an observing eye and an appreciating mind for these minute wonders of Nature, need never be alone. Every nook and corner of the earth, however barren and dreary to superficial minds, has companions for him; and on every path he will find what the Indians call a *rustawallah*, a delightful road-fellow.

To the cryptogamic botanist Nature reveals herself in her wildest, and also in her fairest aspects. He enters into her guarded retreats—retiring spots of luxuriant, refreshing, and enticing beauty, that are hidden from every other eye; where the great world of strife and toil speaks not, and its cares and sorrows are forgotten, and Nature wakes up the dead divinity within, and rouses the soul to purer and nobler purposes. The peculiar haunts of the objects of his search are found on the sides and summits of lofty mountains, amid the dark, lonely recesses of forests; in the bright bosom of rivers, and lakes, and water-falls; on far-off, unvisited moors, where heaven's serene and passionless blue is the only thing of beauty; and in the mossy retreats of dell and dingle, where Titania and her fays might sport away the dreamy noontide hours. There he finds the pictures which the soul treasures most lovingly; and in these by-ways does he gain the truest insight into the mysteries of life. In thus penetrating into the very heart of Nature, with much toil and exertion it may be, he seems to win her confidence, and to earn the right to look into her arcana. By minute contact and continued commune with her alone in the wilderness, he feels in all its fulness and depth the beautiful relationship that exists between the outer and the inner life of creation. To others the landscape may be the mere background of a picture, in the foreground of which human figures are acting; to him its charms are agencies and influences acting on his heart and mingling with his life. The sportsman in search of game frequently wanders into regions that seem primeval in their solitude, and where "human foot had ne'er or rarely been;" but so absorbing is the pursuit in which he is engaged, that he seldom pauses to watch the features of the surrounding scenery, or to notice combinations of objects and effects of light and shade which Nature never displays, except in such unfrequented spots. But to the cryptogamist, on the other hand, these very scenes of Nature lend a nameless charm and interest to the lowly plants he gathers, and are ever after indelibly associated with them in his memory, and are renewed every time he witnesses their faded remains. Hardly a moment passes over the solitary collector amid such secluded scenes, without some grand effect being produced in the surrounding land-

scape, or in the appearance of the sky above him; some wonderful transformation of Nature, as though the spot where he stands were her tiring-room, and she were trying on robe after robe to see which became her best; some striking incident, which might well inspire him with the wish to catch the happy moment, and give it a permanent existence. Such are the simple, refining, and enduring pleasures which the cryptogamic botanist enjoys in the pursuit of his favorite study amid the scenes of Nature.

Add to all these recommendations this last important advantage, that these plants can be observed and collected without interruption throughout the whole year, and in situations where other vegetation is reduced to zero. They can be studied alike under the cloudy skies of December, as when illumined by the sunshine of June. When the flowers and ferns have vanished, when the lights are fled, and the garlands are dead, the deserted banquet-hall of Flora is still relieved by the presence of these humble retainers, whose fidelity is proof against every change of circumstance, and whose better qualities are displayed when the storm is wildest and the desolation most complete. They are no summer friends. As Ruskin has beautifully observed: "Unfading as motionless, the worm frets them not, and the autumn wastes not. Strong in lowliness, they neither blanch in heat, nor pine in frost. To them, slow-fingered, constant-hearted, is intrusted the weaving of the dark eternal tapestries of the hills; to them, slow-pencilled, iris-dyed, the tender framing of their endless imagery. Sharing the stillness of the unimpassioned rock, they share also its endurance; and while the winds of departing spring scatter the white hawthorn-blossoms like drifted snow, and summer duns in the parched meadow the drooping of its cowslip gold, far above among the mountains, the silver lichen-spots rest, starlike on the stone, and the gathering orange-stain upon the edge of yonder western peak reflects the sunsets of a thousand years."—*Foot-Notes from the Page of Nature.*

THE WEATHER AND THE SUN.

By RICHARD A. PROCTOR, B. A.

THERE are few scientific questions of greater interest than the inquiry whether it is possible to find a means of predicting the weather for a long time in advance. In former ages many attempts were made to solve this problem by a reference to the motions of the heavenly bodies. Other methods of prediction were, indeed, in vogue; but I am not here considering ordinary weather portents, or mere scientific schemes for anticipating the weather of two or three coming days: and, with a few trifling exceptions, depending on observations

of plants and animals, it is the case that the only wide rules for predicting weather were based on the motions of the sun and moon, the planets and the stars. It must be remembered that even astronomers of repute placed faith, until quite recent years, in the seemingly absurd tenets of judicial astrology. We cannot greatly wonder, therefore, if the more reasonable thesis, that the heavenly bodies determine weather-changes, was regarded with favor. Accordingly we find Horrox, more than two centuries ago, drawing the distinction here indicated, where he says that, in anticipating "storm and tempest" from a conjunction of Mercury with the Sun, he coincides "with the opinion of the astrologers, but in other respects despises their more puerile vanities." We find Bacon in like manner remarking that "all the planets have their summer and winter, wherein they dart their rays stronger or weaker, according to their perpendicular or oblique direction." He says, however, that "the commixtures of the rays of the fixed stars with one another are of use in contemplating the fabric of the world and the nature of the subjacent regions, but in no respect for predictions." Bacon remarks again that reasonable astrology (*Astrologia sana*) "should take into account the apogees and perigees of the planets, with a proper inquiry into what the vigor of planets may perform of itself; for a planet is more brisk in its apogee, but more communicative in its perigee: it should include, also, all the other accidents of the planet's motions, their accelerations, retardations, courses, stations, retrogradations, distances from the sun, increase and diminution of light, eclipses, etc.; for all these things affect the rays of the planets, and cause them to act either weaker or stronger, or in a different manner."

It is a remarkable circumstance that systems of weather prediction based on such considerations were not quickly exploded, owing to their failure when tested by experience. Yet singularly enough it has scarcely ever happened that any wide system of interpretation has been devised, which has not been regarded with favor by its inventor long after it had been in reality disproved by repeated instances of failure. This remark applies to recent systems as well as to those invented in earlier times. Within the last twenty years, for example, methods of prediction based on the moon's movements, on the conjunctions of the planets, and on other relations, have been maintained with astonishing perseverance and constancy, in the face of what outsiders cannot but regard as a most discouraging want of agreement between the predicted weather and the actual progress of events. Here, as in so many cases of prediction, we find the justice of Bacon's aphorism, "Men mark when they hit, and never mark when they miss."

It is noteworthy, indeed, that the very circumstance which appears to present a fatal objection to all schemes of prediction based on the motions of the celestial bodies, supplies the means of imagining that

predictions have been fulfilled. The objection I refer to is this: we know that the weather is seldom alike over very wide regions, while, nevertheless, the celestial bodies present the same aspect toward the whole extent of such regions, or an aspect so nearly the same as to suggest that the same conditions of weather should prevail if the weather really depended on the position of the heavenly bodies. It appears, then, that the inventor of a really trustworthy system must have a distinct scheme for each part of every continent—nay, of every country, if not of every county. This objection is not taken into account, however, by the inventors of systems, while the fact on which it depends affords the means of showing that each prediction has been fulfilled. Thus, suppose "bad weather and much wind" have been predicted on a certain day, and that day is particularly fine and calm in London. If this were urged as an objection to the soundness of the system, the answer would run somewhat on this wise: "Unquestionably it was fine in London, but in North Scotland (or in France, or Spain, or Italy, as the case may be) there was very gloomy weather, and in Ireland (suppose) quite strong winds are reported to have prevailed in the afternoon." The readiness with which men satisfy themselves in such cases, corresponds with that mischievous ingenuity wherewith foolish persons satisfy themselves that a fortune-teller had foretold the truth, that a dream had been fulfilled, a superstition justified, and so forth.

The tendency, at present, among those who are desirous of forming a scheme of weather prediction, is to seek the origin of our weather-changes in changes of the sun's condition, and, by determining the laws of the solar changes, to ascertain the laws which regulate changes in the weather.

It may be remarked, in passing, that this new phase of the inquiry does not reject planetary influences altogether. The theory is entertained by many well-known students of science that changes in the condition of the sun are dependent on the varying positions of the planets; so that, if it should be established that our weather-changes are connected with solar changes, we should infer that indirectly the planets in their motions rule the weather on our earth.

I propose now to consider the evidence relating to the sun's influence, and to discuss the question (altogether distinct, be it remarked) whether a means of accurate weather prediction may be obtained *if* the sun's influence be regarded as demonstrated.

There is one strong point in favor of the new theory, in the fact that the sun is unquestionably the prime cause of all weather changes. To quote the words of Lieutenant-Colonel Strange, an enthusiastic advocate of the theory (and eager to have it tested at this country's charge), "there can hardly be a doubt that almost every natural phenomenon connected with the climate can be distinctly traced to the sun as the great dominating force, and it is a natural inference" (though not, as

he says, an unavoidable one) "that the changes, and what we now call the uncertainties of climate, are connected with the constant fluctuations which we know to be perpetually occurring in the sun itself." I may proceed, indeed, in this place, to quote the following words, in which Colonel Strange enunciates the theory itself which I am about to discuss, and its consequences: "The bearing of climatic changes on a vast array of problems connected with navigation, agriculture, and health, need but be mentioned to show the importance of seeking in the sun, where they doubtless reside, for the causes which govern these changes. It is indeed my conviction that, of all the fields now open for scientific cultivation, there is not one which, quite apart from its transcendent philosophical interest, promises results of such high utilitarian value as the exhaustive systematic study of the sun."

It cannot be doubted, I think, that, if any thing like what is here promised could be hoped for from the study of the sun, it would be a matter of more than national importance to undertake the task indicated by Colonel Strange. The expense of new observatories for this special subject of study would, in that case, be very fully repaid. It would be worth while to employ the most skilful astronomers at salaries comparable with those which are paid to our Government ministers; it would be well to secure, on corresponding terms, the advice of those most competent to decide on the instrumental requirements of the case; and, in fact, the value of the work which is at present accomplished at Greenwich, great though that value is, would sink into utter insignificance, in my judgment, compared with the results flowing in the supposed case from the proposed "exhaustive and systematic study" of the great central luminary of the planetary system.

The subject we are to discuss is manifestly, therefore, of the utmost importance, and cannot be too carefully dealt with. It would be a misfortune on the one hand to be led by careless reasoning to underestimate the chances in favor of the proposed scheme, while, on the other, it would be most mischievous to entertain unfounded expectations where the necessary experiments must be of a costly nature, and where science would be grievously discredited, should it be proved that the whole scheme was illusory.

We note, first, that, besides being "the great dominating force" to which all natural phenomena connected with climate are due, the sun has special influence on all the most noteworthy *variations* of weather. The seasons are due to solar influence; and here we have an instance of a power of prediction derived from solar study, though belonging to a date so remote that we are apt to forget the fact. It seems so obvious that summer will be on the whole warmer than winter, that we overlook the circumstance that, at some epoch or other, this fact, at least in its relation to the apparent motions of the sun, must have been recognized as a discovery. Men must at one time have learned, or perhaps we should rather say each race of men must at one time

have noticed, that the varying warmth on which the processes of vegetation depend, corresponds with the varying diurnal course of the sun. So soon as this was noticed, and so soon as the periodic nature of the sun's varying motions had been ascertained, men had acquired in effect the power of predicting that, at particular times or seasons, the weather on the whole would be warmer than at other seasons. In other words, so soon as men had recognized the period we call the *year*, they could predict that one half of each year would be warmer than the other half. Simple as this fact may seem, it is important to notice it as the beginning of weather-prediction; for, as will presently appear, it has an important bearing on the more complex questions at present involved in the prognostication of weather-changes.

It became manifest, almost as soon as this discovery had been made, that the weather of particular days, or even of weeks and longer periods, could not, by its means, be predicted. A week in summer may be cold, and a week in winter may be warm; nor, so far as is even yet known, is there a single part of any year the temperature of which can be certainly depended upon, at least within the temperate zone. In certain tropical regions there are tolerably constant weather variations; but, so far is this from being the case in the temperate zones of either hemisphere, that it is impossible to affirm certainly, even that during a week or fortnight at any given summer season there will be one hot day, or that during a corresponding period in winter there will be one day of cold weather.

It became manifest also, at an early epoch, that terrestrial conditions must be intimately involved in all questions of weather, since the year in different countries in the same latitudes presents different features. Such differences are of two kinds—those which have a tendency to be constant, and those which are in their nature variable. For example, the annual weather, in Canadian regions having the same range of latitude as Great Britain, differs always to a very marked degree, though not always to the same degree, from that which prevails in this country; here, then, we have a case of a constant difference due unquestionably to terrestrial relations. Again, when we have a hot or dry summer in this country, warm or damp weather may prevail in other countries in the same latitudes, and *vice versa;* differences of this kind are ordinarily[1] variable, and in the present position of weather-science are regarded as accidental.

[1] I use this qualifying word, because some differences of the kind are more or less regular. Thus, when there is a dry summer in certain regions in the west of Europe, there is commonly a wet summer in easterly regions in the same latitude, and *vice versa*, the difference simply depending on the height at which the clouds travel which are brought by the southwesterly counter-trade winds. When these clouds travel high, they do not give up their moisture until they have travelled far inland or toward the east; when they travel low, their moisture is condensed so soon as they reach the western land-slopes. It is not uncommonly the case again that, when we in England have dry summers, much rain falls on the Atlantic, and our drought is simply due to the fall of

Hitherto, weather-science has depended solely on the study of these terrestrial effects as they vary under varying conditions. Modern meteorological research is confined to the record and study of the actual condition of the weather from day to day at selected stations in different countries. It cannot be denied that the inquiry has not been attended with success. At vast expense, millions of records of heat, rainfall, winds, clouds, barometric pressure, and so on, have been secured; but hitherto no law has been recognized in the variations thus recorded—no law, at least, from which any constant system of prediction for long periods in advance can be deduced.

On this point I shall quote, first, a remarkable saying of Sir W. Herschel's, which appears to me, like many such sayings of his, to be only too applicable to the present state of science. In endeavoring to interpret the laws of weather, "we are in the position," Herschel remarks, "of a man who hears at intervals a few fragments of a long history related in a prosy, unmethodical manner. A host of circumstances omitted or forgotten, and the want of connection between the parts, prevent the hearer from obtaining possession of the entire history. Were he allowed to interrupt the narrator, and ask him to explain the apparent contradictions, or to clear up doubts at obscure points, he might hope to arrive at a general view. The questions that we would address to Nature are the very experiments of which we are deprived in the science of meteorology."

The late Prof. De Morgan, indeed, selected meteorology as the subject on which, above all others, systematic observations had been most completely wasted—as a special instance of the failure of the true Baconian method (which, be it noticed, is not, as is so commonly supposed, the modern scientific method). "There is an attempt at induction going on," says De Morgan, "which has yielded little or no fruit, the observations made in the meteorological observatories. This attempt is carried on in a manner which would have caused Bacon to dance for joy" (query); "for he lived in times when chancellors did dance. Russia, says M. Biot, is covered by an army of meteorographs, with generals, high officers, subalterns, and privates, with fixed and defined duties of observation. Other countries, also, have their systematic observations. And what has come of it? Nothing, says M. Biot, and nothing will ever come of it: the veteran mathematician and experimental philosopher declares, as does Mr. Ellis" (Bacon's biographer), "that no single branch of science has ever been fruitfully explored in this way." A special interest attaches, I may remark, to the opinion of M. Biot, because it was given upon the proposal of the French Government to construct meteorological observatories in Algeria.

It is well known that our Astronomer Royal holds a similar opin-

this rain before the clouds from the southwest have reached us. More commonly, however, drought in England is due to the delay of the downfall, in consequence of the clouds from the southwest travelling at a greater height than usual.

ion. De Morgan thus quaintly indicates his interpretation of one particular expression of Sir G. Airy's opinion: "In the report to the Greenwich Board of Visitors, for 1867, the Astronomer Royal, speaking of the increase of meteorological observatories, remarks: 'Whether the effect of this movement will be that millions of useless observations will be added to the millions that already exist, or whether something may be expected to result which will lead to a meteorological theory, I cannot hazard a conjecture.' This *is* a conjecture, and a very obvious one; if Mr. Airy would have given 2¾*d.* for the chance of a meteorological theory formed by masses of observations, he would never have said what I have quoted."

The simple combination of terrestrial considerations with the effects due to the sun's varying daily path having thus far failed to afford any interpretation of the varying weather from year to year, it is natural to inquire whether the variations in the sun's condition from year to year may not supply the required means of interpreting, and hence of predicting, weather-changes. We know that the sun's condition does vary, because we sometimes see many large spots upon his surface, whereas at others he has no spots, or few and small ones. We can scarcely doubt that these variations affect the supply of heat and light, as well as of chemical action and possibly of other forms of force; and hence we are certainly dealing with a *vera causa*, though whether this real cause be an efficient cause of weather-changes remains yet to be determined.

It may perhaps be as well to inquire, however, in the first place, whether any peculiarities of weather can be traced to another circumstance which ought to be at least as efficient, one would suppose, as any changes in the sun's action due to the spots. I refer to his varying distance from the earth. It is known doubtless to all my readers that, in June and July, although these are our summer months, the sun is farther away than in December; and this, not by an inconsiderable distance, but by more than 3,000,000 miles. Accordingly, on a summer day in our hemisphere, we receive much less heat than is received on a summer day in the Southern Hemisphere. Or, instead of comparing our summer heat with summer heat in the Southern Hemisphere, we may make comparison between the quantity of heat received by the whole earth on a day in June and on a day in December. Either way of viewing the matter is instructive; and I believe many of my readers will be surprised when they hear what is the actual amount of difference.

We receive in fact, on June 30th, less heat and light than dwellers at our antipodes receive on December 30th, by the amount which would be lost if an opaque disk, having a diameter equal to one-fourth of the sun's,[1] came upon the sun's face as seen on December 30th at

[1] It is easily shown that such would be the size of the imagined black disk. For the sun's distance varies from about 93,000,000 miles to about 90,000,000, or in the propor-

our antipodes. It need hardly be said that no spots, whose effects would be comparable with those produced by such a disk of blackness, have ever been seen upon the face of the sun. Spots are not black or nearly black, even in their very nucleus. The largest ever seen has not had an extent approaching that of our imagined black disk, even when the whole dimensions of the spot—nucleus, umbra, and penumbra—have been taken into account. Moreover, all round a spot there is always a region of increased brightness, making up to a great degree, if not altogether, for the darkness of the spot itself. So that unquestionably the summer heat in the Southern Hemisphere exceeds the summer heat in our hemisphere to a much more marked degree than the heat given out by the sun when he is without spots exceeds the heat of a spotted sun.

It is, however, rather difficult to ascertain what effect is to be ascribed to this peculiarity. It is certain that the Australian summer differs in several important respects from the European summer; but it is not easy to say how much of the difference is due to the peculiarity we have been considering, and how much to the characteristic distinction between the northern and southern halves of the earth—the great excess of water-surface over land-surface in the Southern Hemisphere. It is worthy of notice, however, that even in this case, where we cannot doubt that a great difference must exist in the solar action at particular seasons, we find ourselves quite unable to recognize any peculiarities of weather as *certainly* due to this difference.

I have spoken of a second way of viewing the difference in question, by considering it as it affects the whole earth. The result is sufficiently surprising. It has been shown, by the researches of Sir J. Herschel and Pouillet, that on the average our earth receives each day a supply of heat competent to heat an ocean, 260 yards deep over the whole surface of the earth, from the temperature of melting ice to the boiling-point. Now, on or about June 30th the supply is one-thirtieth less, while on or about December 30th the supply is one-thirtieth greater. Accordingly, on June 30th, the heat received in a single day would be competent only to raise an ocean 251⅓ yards deep from the freezing to the boiling point, whereas on December 30th the heat received from the sun would so heat an ocean 268⅔ yards deep. The mere excess of heat, therefore, on December 30th, as compared with June 30th, would suffice to raise an ocean, more than 17 yards deep and covering the whole earth, from the freezing-point to the temperature of boiling water! It will not be regarded as surprising if terrestrial effects of some importance should follow from so noteworthy an

tion of 31 to 30. Hence the size of his disk varies in the proportion of 31 times 31 to 30 times 30, or as 961 to 900. The defect of the latter number 900 amounts to 61, which is about a sixteenth part of the larger number. But a black disk having a diameter equal to a quarter of the sun's would cut off precisely a sixteenth part of his light and heat, which was the fact to be proved.

excess, not merely of light and heat, but of gravitating force, of magnetic influence, and of actinic or chemical action, exerted upon the earth as a whole. Accordingly we find that there is a recognizable increase in the activity of the earth's magnetism in December and January as compared with June and July. But, assuredly the effect produced is not of such a character as to suggest that we should find the means of predicting weather, *if* it were possible for us *now* to discover any solar law of change resulting in a corresponding variation of solar action upon the earth.

This leads us to consider the first great law of solar change as distinguished from systematic variations like the sun's varying change of distance and his varying daily path on the heavens. This law is that which regulates the increase and decrease of the solar spots within a period of about eleven years. The sun's condition does not, indeed, admit of being certainly predicted by this law, since it not unfrequently happens that the sun shows few spots for several weeks together, in the very height of the time of spot-frequency, while on the other hand it often happens that many and large spots are seen at other times. Nevertheless, this general law holds, that, on the whole, and taking one month with another, there is a variation in spot-frequency, having for its period an interval of rather more than eleven years.

Now, the difference between a year of maximum spot-frequency and one of minimum frequency is very noteworthy, notwithstanding the exceptional features just mentioned, which show themselves but for short periods. This will be manifest on the consideration of a few typical instances. Thus, in the year 1837, the sun was observed on 168 days, during which he was not once seen without spots, while no less than 333 new groups made their appearance. This was a year of maximum spot-frequency. In 1843, the sun was observed on 312 days, and on no less than 149 of these no spots could be seen, while only 34 new groups made their appearance. This was a year of minimum spot-frequency. Passing to the next maximum year, we find that in 1848 the sun was observed on 278 days, during which he was never seen without spots, while 330 new spots made their appearance. In 1855 and 1856 together, he was observed on 634 days, on 239 of which he was without spots, while only 62 new groups made their appearance. The next maximum was not so marked as usual, that is, there was not so definite a summit, if one may so speak, to the wave of increase; but the excess of spot-frequency was none the less decided. Thus, in the four years, 1858–'61, the sun was observed on 335, 343, 333, and 322 days, *on not one of which he was spotless*, while the numbers of new groups for these four years were, respectively, 202, 205, 211, and 204. The minimum in 1867 was very marked, as 195 days out of 312 were without spots, and only 25 new groups appeared. The increase after 1867 was unusually rapid, since in 1869 there were no spotless days,

and 224 new groups were seen, though the sun was only observed on 196 days. The number of spots in 1870, 1871, and 1872, as well as their magnitude and duration, has been above what is usual, even at the period of maximum spot-frequency.

From all this it will be manifest that we have a well-marked peculiarity to deal with, though not one of perfect uniformity. Next to the systematic changes already considered, this alternate waxing and waning of spot-frequency might be expected to be efficient in producing recognizable weather-changes. Assuredly, if this should not appear to be the case, we should have to dismiss all idea that the sun-spots are weather-rulers.

Now, from the first discovery of spots, it was recognized that they must, in all probability, affect our weather to some degree. It was noticed, indeed, that our auroras seemed to be in some way influenced by the condition of the sun's surface, since they were observed to be more numerous when there are many spots than when there are few or none. Singularly enough, the effect of the spots on temperature was not only inquired into much later (for we owe to Cassini and Mairan the observation relating to auroras), but was expected to be of an opposite character from that which is in reality produced. Sir W. Herschel formed the opinion that, when there are most spots, the sun gives out most heat, notwithstanding the diminution of light where the spots are. He sought for evidence on this point in the price of corn in England, and it actually appeared, though by a mere coincidence, that corn had been cheapest in years of spot-frequency, a result regarded by Herschel as implying that the weather had been warmer on the whole in those years. It was well pointed out, however, by Arago, that "in these matters we must be careful how we generalize facts before we have a very considerable number of observations at our disposal." The peculiarities of weather in a single and not extensive country like England are quite insufficient to supply an answer to the wide question dealt with by Herschel. The weather statistics of many countries must be considered and compared. Moreover, very long periods of time must be dealt with.[1]

[1] When Herschel made his researches into this subject, the law of spot-frequency had not been discovered. He would probably have found in this law, as some have since done, the explanation of the seven years of plenty and the seven years of famine, typified by the fat kine and lean kine of Joseph's dream. For, if there were a period of eleven years in which corn and other produce of the ground waxed and waned in productiveness, it would be not at all unlikely that, when ever this waxing and waning chanced to be unusually marked, there would result two series of poor and rich years apparently ranging over fourteen instead of eleven years. We have seen, above, that the waves of spot-waxing and spot-waning are not all alike in shape and extent. Whenever, then, a wave more marked than usual came, we should expect to find it borrowing, so to speak, both in trough and crest, from the waves on either side. It would require but a year or so either way to make the wave range over fourteen years; and observed facts, even during the last half-century only, show this to be no unlikely event.

M. Gautier, of Geneva, and, later, MM. Arago and Barratt, made a series of researches into the tabulated temperature at several stations, and for many successive years. They arrived at the conclusion that, on the whole, the weather is coolest in years of spot-frequency.

But recently the matter has been more closely scrutinized, and it has been found that the effects due to the great solar-spot period, although recognizable, are by no means so obvious as had been anticipated.

These effects may be divided into three classes: those affecting (1) temperature, (2) rainfall, and (3) terrestrial magnetism.

As respects the first, it has been discovered that, when *underground* temperatures are examined, so that local and temporary causes of change are eliminated, there is a recognizable diminution of temperature in years when spots are most frequent. We owe this discovery to Prof. C. P. Smyth, Astronomer Royal for Scotland. The effect is very slight; indeed, barely recognizable. I have before me, as I write, Prof. Smyth's chart of the quarterly temperatures from 1837 to 1869, at depths of 3, 6, 12, and 24 French feet. Of course, the most remarkable feature, even at the depth of 24 feet, is the alternate rise and fall with the seasons. But it is seen that, while the range of rise and fall remains very nearly constant, the crest and troughs of the waves lie at varying levels. After long and careful scrutiny I find myself compelled to admit that I cannot find the slightest evidence in *this* of a connection between underground temperatures and the eleven-years period of sun-spots. I turn, therefore, to the chart in which the annual means are given; and, noting in the means at the lesser depths "confusion worse confounded" (this, of course, is no fault of Prof. Smyth's, who here merely records what had actually taken place), I take the temperatures at a depth of 24 French feet. Now, neglecting minor features, I find the waves of temperature thus arranged: They go down to a little more than 46½ degrees of the common thermometer in 1839–'40; rise to about 47¾ degrees in 1847; sink to 47¼ degrees in 1849; mount nearly to 47¾ degrees again in 1852–'53; are at 47 degrees in 1856–'57; are nearly at 48 degrees in 1858–'59; then they touch 47 degrees three times (with short periods of rising between), in 1860, 1864, and 1867; and rise above 47½ degrees in 1869. Now, if we remember that there were maxima of spots in 1837, 1848, 1859–'60, and 1870, while there were minima in 1843, and in 1855–'56, I think it will be found to require a somewhat lively imagination to recognize a very striking association between the underground temperature and the sun's condition with respect to spots. If many spots imply diminution of heat, how does it come that the temperature rises to a maximum in 1859, and again in 1869? if the reverse, how is it that there is a minimum in 1860? I turn, lastly, to the chart in which the sun-spot waves and the temperature-waves are brought into actual comparison, and I find myself utterly unable to recognize the slightest as-

sociation between them. Nevertheless, I would not urge this with the desire of in any way throwing doubt upon the opinion to which Prof. Smyth has been led, knowing well that the long and careful examination he has given to this subject in all its details may have afforded ample though not obvious evidence for the conclusions at which he has arrived. I note, also, that, as he points out, Mr. Stone, director of the Cape Town Observatory, and Mr. Cleveland Abbe, director of the Cincinnati Observatory, have since, "but it is believed quite independently, published similar deductions touching the earth's temperature in reference to sun-spots." All I would remark is, that the effect is very slight, and very far from being obvious at a first inspection.

Next as to rainfall and wind.

Here, again, we have results which can hardly be regarded as striking, except in the forcible evidence they convey of the insignificance of the effects which are to be imputed to the great eleven-year spot period. We owe to Mr. Baxendell, of Manchester, the most complete series of investigations into this subject. He finds that, at Oxford, during the years when sun-spots were most numerous, the amount of rainfall under west and southwest winds was greater than the amount under south and southeast winds; while the reverse was the case in years when spots were few and small. Applying corresponding processes to the meteorological records for St. Petersburg, he finds that a contrary state of things prevailed there. Next we have the evidence of the Rev. R. Main, director of the Radcliffe Observatory at Oxford, who finds that westerly winds are slightly more common when sun-spots are numerous than at other times. And, lastly, Mr. Meldrum, of Mauritius, notes that years of spot-frequency are characterized, on the whole, by a greater number of storms and hurricanes than years when the sun shows few spots.

The association between the sun-spot period and terrestrial magnetism is of a far more marked character, though I must premise that the Astronomer Royal, after careful analysis of the Greenwich magnetic records, denies the existence of any such association whatever. There is, however, a balance of evidence in its favor. It seems very nearly demonstrated that the daily sway of the magnetic needle is greatest when sun-spots are numerous, that magnetic storms are somewhat more numerous at such times, and that auroras are also more commonly seen. Now, it has been almost demonstrated by M. Marié Davy, chief of the meteorological division in the Paris Observatory, that the weather is affected in a general way by magnetic disturbances. So that we are confirmed in the opinion that, indirectly, if not directly, the weather is affected to some slight degree by the great sun-spot period.

Still, I must point out that not one of these cases of agreement has any thing like the evidence in its favor which had been found for an association between the varying distance of Jupiter and the sun-spot changes. For eight consecutive maxima and minima this association

has been strongly marked, and might be viewed as demonstrated—only it chances, unfortunately, that, for two other cases, the relation is *precisely reversed;* and, in point of fact, whereas the period now assigned to the great sun-spot wave is eleven years and rather less than *one* month, Jupiter's period of revolution is eleven years and about *ten* months, a discrepancy of nine months, which would amount to five and a half years (or modify perfect agreement into perfect disagreement) in seven or eight cycles.

But, accepting the association between weather and the sun-spot changes as demonstrated (which is granting a great deal to the believers in solar weather-prediction), have we any reason to believe that by a long-continued study of the sun the great problem of foretelling the weather can be solved? This question, as I have already pointed out, must not be hastily answered. It is one of national, nay, of cosmopolitan importance. If answered in the affirmative, there is scarcely any expense which would be too great for the work suggested; but all the more careful must we be not to answer it in the affirmative, if the true answer should be negative.

But it appears to me that so soon as the considerations dealt with above have been fairly taken into account, there can be no possible doubt or difficulty in replying to the question. The matter has, in effect, though not in intention, been tested experimentally, and the experiments, when carried out under the most favorable conditions, have altogether failed. To show that this is so, I take the position of affairs before Schwabe began that fine series of observations which ended in the discovery of the great spot-period of eleven years. Let us suppose that at that time the question had been mooted whether it might not be possible, by a careful study of the sun, to obtain some means of predicting the weather. The argument would then have run as follows: "The sun is the great source of light and heat; that orb is liable to changes which must in all probability affect the supply of light and heat; those changes may be periodical, and so predictable; and, as our weather must to some extent depend on the supply of light and heat, we may thus find a means of predicting weather-changes." The inquiry might then have been undertaken, and undoubtedly the great spot-period would have been detected, and with this discovery would have come that partial power of predicting the sun's condition which we now possess—that is, the power of saying that in such and such a year, taken as a whole, spots will be numerous or the reverse. Moreover, meteorological observations conducted simultaneously would have shown that, as the original argument supposed, the quantity of heat supplied by the sun varies to a slight degree with the varying condition of the sun. Corresponding magnetic changes would be detected; and also those partial indications of a connection between phenomena of wind and rain and the sun's condition which have been indicated above. All this would be exceedingly interesting to men of

science. *But*, supposing all this had been obtained at the nation's expense, and the promise had been held out that the means of predicting weather would be the reward, the non-scientific tax-paying community might not improbably inquire what was the worth of these discoveries to the nation or to the world at large. Be it understood that I am not here using the *cui-bono* argument. As a student of science, I utterly repudiate the notion that, before scientific researches are undertaken, it must be shown that they will *pay*. But it is one thing to adopt this mean and contemptible view of scientific research, and quite another to countenance projects which are based *ab initio* upon the ground that they will more than repay their cost. Now, I think, if the nation made the inquiry above indicated, and under the circumstances mentioned, it would be very difficult to give a satisfactory reply. The tax-payers would say: "We have supplied so many thousands of pounds to found national observatories for the cultivation of the physics of science, and we have paid so many thousands of pounds yearly to the various students of science who have kindly given their services in the management of these observatories; let us hear what are the utilitarian results of all this outlay. We do not want to hear of scientific discoveries, but of the promised means of predicting the weather." The answer would be: "We have found that storms in the tropics are rather more numerous in some years than others, the variations having a period of eleven years; we can assert pretty confidently that auroras follow a similar law of frequency; southwest winds blow more commonly at Oxford but less commonly elsewhere, when the sun-spots, following the eleven-year period, are at a maximum; and more rain falls with southwesterly winds than with southeasterly winds at Oxford and elsewhere, but less at St. Petersburg and elsewhere, when sun-spots are most numerous, while the reverse holds when the spots are rare." I incline to think that, on being further informed that these results related to averages only, and gave no means of predicting the weather for any given day, week, or month, even as respects the unimportant points here indicated, the British tax-payer would infer that he had thrown away his money. I imagine that the army of observers who had gathered these notable results would be disbanded rather unceremoniously, and that for some considerable time science (as connected, at any rate, with promised "utilitarian" results) would stink in the nostrils of the nation.

But this is very far, indeed, from being all. Nay, we may almost say that this is nothing. Astronomers *know* the great spot-period; they have even ascertained the existence of longer and shorter periods less marked in character; and they have ascertained the laws according to which other solar features besides the spots vary in their nature. It is certain that whatever remains to be discovered must be of a vastly less-marked character. If, then, the discovery of the most striking law of solar change has led to no results having the slightest

value in connection with the problem of weather-prediction, if periodic solar changes of a less marked character have been detected which have no recognizable bearing on weather-changes, what can be hoped from the recognition of solar changes still more recondite in their nature? It is incredible that the complex phenomena involved in meteorological relations regarded as a whole, those phenomena which are but just discernibly affected by the great sun-spot period, should respond to changes altogether insignificant even when compared with the development and decay of a single small sun-spot. It appears to me, therefore, that it is the duty of the true lover of science to indicate the futility of the promises which have been mistakenly held out; for it cannot be to the credit of science, or ultimately to its advantage, if government assistance be obtained on false pretences for any branch of scientific research.

ORIENTALS AT VIENNA.

THE anticipations with regard to the appearance made by Orientals at Vienna will be realized to the full, and doubtless the contact between the East and West will prove of mutual advantage. In fact, the peculiarly happy situation of the Austrian capital has not only given this Exhibition its distinctive character, but has developed its proportions in a degree that has falsified all the original calculations. It soon became evident that circumstances would take it out of the category of those which had preceded it; that it might open new markets which were practically limitless, and that it would throw new and valuable lights upon hackneyed and familiar subjects. It was seen that it would reproduce, on an immeasurably greater scale, such cosmopolitan gatherings of traders as assembled at the great fairs of Leipsic or Nijni-Novgorod; that it would drag into open day the rarer contents of Oriental bazaars, and expose them side by side with the goods produced in Western manufactories and sold by Western shopkeepers. There would be unrivalled opportunities of making comparisons and drawing conclusions, of learning practical lessons and exploding antiquated prejudices. So it seems likely to prove; nor will either half of the world have much reason to triumph over the other. We need not advertise the wonders of our Western civilization. If we are not much in the way of boasting of them as against the benighted East, it is simply because we enjoy the serene self-complacency of indisputable superiority. To a certain extent we are justified by the results of a rapidly-accelerating progress, which shows itself in the swift growth of our material prosperity. We work at the highest pressure; we invoke science to our assistance, and foster a restless rivalry that drives invention forward at express speed; we

multiply labor by the introduction of mechanical improvements; and we supply our homes with luxuries that have become necessaries at extraordinarily economical rates. In short, we produce quickly and cheaply, and in all that relates to action we leave the dreamy East immeasurably behind, as the Easterns are ready enough to acknowledge, and, for the most part, rather with commiseration than envy. But, on the other hand, in much that is highest and most perfect in art we are the scholars and they the teachers. Our best-informed and most experienced technical and practical men are the most ready to acknowledge this. It is not wealthy connoisseurs and capricious *dilettanti* who lounge about the courts of Japan, China, and Turkey, cheapening the strangely attractive wares which are exposed by the merchants from those distant countries. It is the European manufacturers and tradesmen—especially the English—who rush into the Eastern departments, eagerly bidding against each other for every thing that strikes their fancy. This is one of the most characteristic features of the Vienna Exhibition. On no previous occasion of the kind has there been such wholesale buying and selling in the very earliest days, and the traffic goes forward most briskly in the Oriental quarters. As yet, Japan has not cleared her goods at the custom-house; China has scarcely imported the better part of hers. Those countries cannot as yet pretend to set a price upon their wares, while the prices fixed by the Persians seem high enough in all conscience, and the Ottomans are following suit after the time-honored fashion of Eastern dealers. Yet already the choicest of the Persian prayer-carpets are snatched up at the high prices set upon them; the best of the Japanese porcelain, bronzes, *cloisonnée* ware, and silks, have been sold several times over, the charges being left to the conscience of the commissioners, and the cards of the fortunate purchaser lying on the fragments of the torn tickets that had been affixed by rejected bidders; while even in Turkey and Tunis, which come far behind Japan and Persia in taste and quality of workmanship, many of the goods have changed owners already, the Prince of Wales being among the earliest and most considerable buyers.

The truth is, the more closely we look into the special productions of the East, the more we recognize its incontestable superiority in design and color, and in perfection of form and finish. The Orientals have plenty of time, no doubt, and do not grudge it; they can afford to work leisurely and carefully where we must economize labor by the rapidity of our processes and the multiplying power of our machinery. But then they have taste as well, and a taste which is older than schools of art, and seems nearly independent of technical education. Compare the graceful turbans and draperies of the Oriental with the stiff "chimney-pot," cutaway, and trousers of the Frank. The latter, although open to criticism even as convenient wear, doubtless look more like business. They give the idea of stripping easily

for a hard day's work, and suggest readiness to answer the calls of any emergency. They are turned out comparatively cheaply to cut-and-dry patterns. The former are the signs of a languid yet not unfruitful existence. But they express the intuitive gracefulness of ideas evolved in a calm fulness of thought that will not be hurried; they show an originality and versatility of fancy whose inspirations may have been sought in the dreamy fumes of opium. Go to the remotest East of Asia, seek the Oriental on his own proper ground, and you seldom take him at a disadvantage. In his own unpretending way, the peasant who weaves mats of bamboo or moulds vessels of common clay in his retired village is as much of an artist as the skilled workman of Yeddo who lacquers cabinets in the most delicate plaques of veneer, or chases the bronze incense-burners that are to swing in the temples. When the Oriental breaks down is when he takes to imitating the European, as he has begun to do in these latter days. The Japanese sometimes turn from their own beautiful specimens of Kago and Satsuma porcelain to reproduce the fashions and colors of Parisian and English crockery, while the Turks back their clumsy machinery against the looms of Mancester in calicoes and cottons. Happily these follies of imitation are as yet rare; and probably the profits of this novel trade will not encourage the enterprising imitators to persevere. The East has much to learn from the West, and the lessons that will prove of most service to it go to the very groundwork of its society. It has yet to be enlightened as to the advantages of civil and religious liberty and education, the value of time, and the necessity of system and method. All this it is now learning, and in some matters of detail its education is going on only too rapidly. Doubtless sooner or later it will come to our markets for machinery which will enable it to make at home what it imports at present from abroad. But some of its tentative advances in this direction are premature and injudicious, to say the least, and, judging by certain samples of its imitative skill, it seems inclined to precipitate a competition whose unfortunate results in price and quality may cause it permanent discouragement.

However, it is not our purpose now to discuss the points on which we may teach the Orientals, but rather to glance at some of those where we are the scholars. There is a great deal in the Eastern departments of the Vienna Exhibition which is chiefly interesting as showing their relative backwardness. Some of them, for instance, send complete samples of their cereals and vegetable productions, and and these are curious as illustrating the advantages of soil and climate which yield them, in spite of the most backward husbandry and the most primitive implements, returns of twenty, fifty, or a hundred fold. But only turn to their show in the arts, and some of them may almost set criticism at defiance. By general consent, and beyond all comparison, the first place must be assigned to Japan. The Japanese does most things unlike the rest of the world. His method of han-

dling his tools is precisely the opposite of ours. He draws his plane toward him, works his saw in the reverse direction, taps with the side of his queer hammer, and handles his quaintly-chased graving tool in a way at which an English workman would stare. Yet, whether he is laying the shingles on the roof of a cottage, or chasing one of those wonderfully elaborate caskets in metal-work, what English workman can approach him? His ideas discover an endless originality; individual impulse, rather than education, seems to inspire his fancy, although it may work according to received traditions of the quaint or beautiful; and, look where we will through a most miscellaneous collection, we can scarcely see a trace of servile repetition. In his pictorial art he can convey a world of expression and suggestion in the very smallest number of touches. Yet when it pleases him to finish, as when he is painting on his delicate porcelain, he is scarcely to be surpassed in harmonious minuteness. As for his colors, you may puzzle out his secret if you can; at least he shows you in an open case the chemicals which, as he professes, form his ingredients. All that can be said is, that none of the numerous attempts at imitation have ever proved to be any thing approaching a success. That strange superiority in color, not only in the tints, but in their management, is to be remarked in every one of the Oriental courts. The silks of China excel even those of Japan, in their bright blues and gorgeous crimsons; while, for softened brilliancy and exquisite delicacy of blending, the Persian carpets are confessedly unequalled. The invariably subdued beauty of these patterns argues something more than great mechanical perfection in the arts of color-making and dyeing. It is proof of a general purity of taste on the part of the Oriental purchasers for whom the fabrics were originally intended; for, although many of the best may now be consigned to Europe, the manufacture, precisely as we see it, has been practised from time immemorial; there are carpets in the Exhibition called modern by comparison, although they may date back for a century or so, and these are of patterns exactly similar to the latest ones. In every thing exhibited from China and Persia, the work is almost invariably good, and the designs felicitous; although, except in certain specialties, they cannot vie with Japan, yet every now and then one stumbles upon something that is extremely beautiful in art. So much can hardly be said of Turkey. Turkey makes a very imposing display; the Sultan contributed £100,000 toward forming the collection, and some of the great merchants in Constantinople, Smyrna, and elsewhere, have apparently done their best to advertise themselves. There is a good deal shown in Turkey, as well as in Tunis, that would have attracted great admiration had there been no Japan and no China to provoke unfavorable comparison. The famous Turkey carpets can scarcely be said to be satisfactorily represented. The very best, beautiful as the texture is, fall far short, even in that respect, of the Persian; while the contrasts displayed in the body of

the Turkish patterns are too often disagreeably violent. But for the most part the carpets exhibited are of a very ordinary class indeed. The inlaid *marqueterie* and cabinet-work seems rude in design and coarse in execution, if we measure it against the Japanese standards. The carved olive-wood from Jerusalem recalls the pedlers' hawking goods made for sale at the doors of the Holy Sepulchre. Here and there are some exquisite arms among many that are inferior; but even the very best of them are excelled by the Persians. There are graceful shapes in the pottery, but they are not unfrequently marred by defects in the workmanship. There is a great collection of figures in the various national costumes, and the dresses strike one as being somewhat incongruous. On the whole, the only articles in which Turkey may be said to show to decided advantage are some extremely rich furniture stuffs, the choicest of which seem to have been already sold or removed, and the dyed morocco, which, in its vividness of color, shames any thing that can be shown by the West. It must be remembered, however, that the Turk gives almost as many months to the dyeing process as the European allows days. Taste apart, we may perhaps console ourselves for the inferiority which we must confess by repeating that facts like this deliberate process of dyeing furnish the key to much of the Oriental excellence. Time is of no value in the East, and patience and indefatigable perseverance have always been the willing handmaids of their arts and manufactures.—*Saturday Review.*

THE MORBID EFFECTS OF HEAT.

By WM. J. YOUMANS, M. D.

THE healthy human body has a temperature which varies but little either way from 99° Fahr. The heat required to maintain this temperature is derived from the oxidation within the body of the elements of the food. In other words, our bodies are furnaces; the food we take is the fuel which supplies the furnace, and the air we breathe is the draught that keeps the combustion going. The amount of heat thus evolved is, in health, always in excess of that needed to maintain the required temperature. There is, therefore, a constant overplus, a part of which is converted into mechanical work, while the remainder escapes as waste, partly along with the matters passing out of the body through the lungs, kidneys, and skin, and partly by the processes of conduction and radiation.

In estimating the morbid effects of external heat upon the living body, this waste requires to be taken into account, as its fluctuations, through the operation of surrounding conditions, have much to

do with the regulation of the body-temperature. If, by exposure to cold, for example, heat is lost more rapidly from the surface than it is supplied within, its warmth must decrease, and there needs but a few degrees of fall to induce disease; on the other hand, if, by exposure to external heat, loss from the body is impeded, its temperature rises, and disease again results.

In hot climates, or during the hot season in temperate latitudes, we are in contact with an atmosphere which frequently attains a temperature nearly or quite equal to that of the body; and, at such times, our sensations tell us that we are losing heat less easily than during the cooler portions of the year. But, when thus exposed, the extensive evaporating surfaces of the lungs and skin are called into more active play; and, if the air is of average dryness, heat is rapidly thrown off by perspiration, the loss being so nicely adjusted that a uniform temperature of 99° Fahr. is continuously maintained. This heat-regulating function of the organism is one of the marvels of physiology. In spite of the vicissitudes of climate and season, it ever holds the temperature at a uniform degree, and, even under the stress of high artificial heat, is able to keep the balance comparatively unchanged. Blagden and Fordyce exposed themselves in an oven to a heat of 260° Fahr., without serious inconvenience, and with but a slight rise of temperature. But the air was dry, and the heat was kept down by perspiration. The substitution of moist for dry air in the oven hindered evaporation, and the temperature of the body rose rapidly. With this hasty sketch of the heat-producing and heat-regulating functions of the animal economy, we pass to a brief consideration of some of the more important ill-effects resulting from the action of excessive heat on the conditions of health and on the body itself.

High temperature is a powerful aid to decomposition. Dead organic matter, under its influence, speedily decays, giving rise to foul and poisonous products which, escaping into the atmosphere, find their way, sooner or later, into the system. Here they work various forms of mischief. Like sulphuretted hydrogen gas, they may be directly poisonous, or, like carbonic-acid gas, may act by diluting the air, and so, by reducing the normal supply of oxygen, interfere with the due oxygenation and purification of the blood. The filth of towns is always highly charged with organic matter, and this, when rapidly decomposing in the heats of summer, has long been recognized as a prolific source of disease.

Decaying vegetable matter in the soil is held to be the source of malarial poison; and here, again, if moisture is present, decay is always hastened and increased by excessive heat. So great, in the opinion of Dr. Parkes, is the influence of heat on the development and spread of malarious disease, that, in selecting a residence with a view to escaping its effects, he recommends that, in tropical countries, the point be 1,000 or 1,500 feet higher above the source of the poison

than is required in temperate latitudes. The remittent form of malarious fevers, according to Dr. Maclean, "is most prevalent and fatal where high temperatures and malaria act in combination." The same authority also says: "I have, in a great many instances, observed intermittents pass at once into a severe type of the remittent form, apparently from no other cause than the descent from comparatively cool and elevated regions into the heated plains, and this under circumstances where there was no reason to believe that the sufferers had been again exposed to malaria."

In the production and spread of cholera, and yellow fever, excessive heat also has an important share. Both are most intimately associated with decomposing filth; both are conveyable by the putrefying stools of the sick, and both flourish most in hot climates and hot seasons. In the case of cholera, the bad effects of extreme heat are abundantly shown by what has been observed in the tropics. "In Bengal," says Dr. Goodeve (Reynolds's "System of Medicine," vol. i., p. 129), "the hot seasons, including the hot, and dry, and rainy seasons, have witnessed the worst epidemics." The most fatal cholera months, in both tropical and temperate countries, are found between April and September. Among European troops in Bombay, according to Dr. Ewart's tables, which cover a period of eight years, more than 50 per cent. of the cases treated in the six months from April to September died, while but little over 19 per cent. of the cases treated in the other six months of the year were fatal. That the disease occurs in winter is undoubted, but that it is much less general and severe is equally true. Yellow fever, though resembling cholera in many ways, is unlike it in this—a temperature of 70° or 72° Fahr. is absolutely requisite to its development and propagation, and the occurrence of frost at once puts an end to its ravages.

Heat also contributes largely toward the production of diarrhœa, its more common form, in recognition of this, taking the name of summer complaint. The disease is far more common and more fatal in hot than in cold climates, and in the summer season of temperate climates than in the winter. Putrefying organic matter, held in suspension in drinking-water, is, according to Dr. Parkes, one of the most common causes of diarrhœa, and this condition of the water is very frequent in summer, and comparatively rare in winter.

In all these instances heat appears to act not so much upon the body itself as upon the various external agencies influencing health. It is to bad conditions what fire is to powder. If the match is withheld, the powder is harmless; but, as the two are liable to come together, we secure safety by removing the magazine. So the presence of filth in water, in soil, and above-ground, may be innocuous by itself, but let the action of heat touch it off into decomposition, and we at once get the effects in the shape of disease. Heat thus aids the pollution of both air and water, keeps alive and active

the germs of disease in the excreta of the sick, and in both ways favors the spread of contagion.

Its direct action upon the person becomes most apparent when some of the functions are going wrong. When the body is healthy, and proper precautions are taken in its management, there is little to fear from exposure to heat. Observers in tropical countries tell us that excessive heats are borne with impunity by the healthy, and that it is mostly those who are either temporarily or chronically out of order that eventually suffer. Not that the body can bear unlimited exposure to great heat, any more than it can endure continuous exertion, but that it is capable of maintaining itself under even excessive heat, if the exposure is not too prolonged. When its powers are impaired by some local or constitutional complaint, however, and it is less able to do the extra work which the influence of excessive heat imposes, then is the time when even slight exposure may be followed by the most serious consequences.

Authors describe several forms of acute disease that are traceable to heat as the exciting cause, but, as all of these partake more or less of the nature of sunstroke, and as we are writing for the public rather than the physician, it is not necessary here to go into their distinguishing features. Sunstroke, or the disease hitherto passing under that name, though known since early times, is even yet not well understood. Up to within a few years, it was believed by patient and physician alike that, to produce it, the body, and especially the head, must be exposed to the direct rays of the sun. There is now abundance of proof to the contrary. In his admirable little work, entitled "Thermic Fever, or Sunstroke," Dr. H. C. Wood quotes the records of its occurrence in barracks, hospitals, and tents, and not infrequently in the night-time, in many cases without immediate previous exposure to the sun. According to Dr. Bonnyman, as cited by Dr. Wood, "By far the greater number of cases that yearly occur in India are of men who have not been exposed to the sun. It is not unusual for men to go to bed in apparent health, and to be seized during the night; and patients in hospitals, who have been confined to bed for days previously, are frequently the subjects of attack." Dr. Swift testifies to its production by exposure to artificial heat, eleven cases treated by him having been attacked in the laundry of an hotel; while several others occurred in sugar-refineries. Dr. Wood mentions a case of his own, which also originated in a sugar-refinery. Dr. Maclean, in the second volume of Reynolds's "System of Medicine," quotes M. Boudin to the effect that one hundred cases of sunstroke occurred on the French man-of-war Duguesne at Rio Janeiro, most of them at night while the men were lying in their bunks. Much more of similar import might be offered, but enough has been said to show that it is great heat which precipitates the attack, and that it makes little difference whether this come from exposure to the direct rays of the sun,

or from a highly-heated atmosphere, or indeed from some artificial source.

But while heat is rightly regarded as the principal if not the sole exciting cause, there are other conditions, as previously stated, which contribute largely toward bringing on the attack. Of these, overcrowding, and its associate, insufficient ventilation, are among the most important. The histories of the outbreaks that have occurred in barracks, in tents, and on shipboard, refer to these conditions as always present, and also mention that both officers and men in every other way similarly circumstanced, but provided with plenty of room and ventilation, did not suffer.

Another and equally important predisposing cause is the exhaustion produced by prolonged exertion. The fact that a large proportion of the cases occurring in this country are of persons engaged in laborious occupations is evidence of this, and if more is needed it is found in the experience of army-surgeons in India, who state that some of the severest epidemics ever witnessed in that country took place among the troops toward the close of long and fatiguing marches, when not a case was observed while the men were fresh and vigorous.

Want of acclimatization is set down as another powerful predisposing cause. "Foreigners," says Dr. Wood, "are always attacked in much larger numbers than natives of the tropics. It must be remembered, however, that no amount of acclimatization will afford certain protection, as even the Hindoo, born and bred in the stifling air of Bengal, is occasionally attacked.

Tight-fitting clothing, which impedes the circulation and hinders the movements of the body, likewise invites attack. Formerly soldiers in India were dressed, in the hottest weather, with tightly-buttoned coats, stiff leather stocks, heavy cross-belts over the chest, and a cap peculiarly adapted to concentrate the rays of the sun upon the head. When so accoutred, according to the testimony of their medical officers, sunstroke among them was common; and, since this style of dress has been done away with, it is much less frequent.

Persons addicted to spirit-drinking are by many writers believed to furnish a much larger proportion of cases than abstainers.

The presence of a large amount of watery vapor in the air is held, by Parkes and others, to predispose to sunstroke. By opposing evaporation from the surface, it favors the rise of animal temperature.

Other causes predisposing to sunstroke are given by different writers; they are, however, of the same general nature as those already enumerated, being simply conditions which either diminish the powers of the system, or for the time being impose upon them some heavy tax. Whether death from sunstroke is due to the action of heat on the nervous system, or to the coagulation of the muscle-plasma (myosin) of the heart, or to blood-poisoning, or in some cases to one, and in others to another of these causes, as maintained by dif-

ferent physicians, it is not necessary here to inquire. What chiefly concerns us now, having pointed out the principal causes of the disease, is to learn something of its symptoms, how in the absence of the doctor it should be treated, and what to do to avoid it.

The serious disturbance of all the functions occasioned by sunstroke results, as might be expected, in a great variety of symptoms. In a small proportion of cases, however, the attack is so sudden and so quickly fatal that little chance for the development or observance of symptoms is afforded. The patient suddenly falls, gasps a few times, and dies. But, in the majority of instances, premonitory symptoms are present. The more constant, as given by the best authorities, are great heat and dryness of skin, a varying degree of pain in the head, attended oftentimes with giddiness, congestion of the eyes, full, rapid pulse, which grows feeble and irregular as the disease advances, obstinate constipation, irritability of bladder, and great oppression or sense of weight about the region of the heart, with not unfrequently muscular weakness and a disinclination for exertion. If these symptoms continue, the patient soon passes into a state of profound insensibility. The pupils fail to respond to the action of light, and may be somewhat contracted, the breathing becomes hurried and difficult, and the action of the heart is irregular and tumultuous. Convulsions may come on early, or be postponed until late in the disease, or they may be absent altogether. Numerous minor and less constant phenomena have been recorded by different observers; but, when a person is suddenly attacked during exposure to great heat, the symptoms already enumerated will enable any one of ordinary intelligence to recognize the true character of the disease.

Only such measures of treatment will be suggested as any one of common-sense can apply; and they may be the means, if promptly resorted to, of ultimately restoring the patient, when, if nothing were done until the physician arrived, he might then have passed beyond the reach of help.

When the signs of an attack appear, the sufferer should be immediately taken to the nearest shade, preferably in the open air, but, at all events, where the freest ventilation can be secured. His body should at once be stripped, and the head, neck, and chest, continuously drenched with cold water. Let this be followed up, not timidly, but with boldness, until respiration is reëstablished, after which it may be applied at short intervals, until a perceptible diminution of the temperature of the body has taken place, or until the doctor arrives. It is the great heat of the body that menaces life, and, the sooner this can be reduced into the neighborhood of the natural temperature, the better for the patient. In rare instances this free use of cold water, by the powerful impression it makes on the nervous system, excites convulsions, in which case it may be discontinued, and rubbing the surface with pounded ice resorted to. An injection of ice-cold water,

as recommended by Dr. Parkes, may, at the same time, be given. When he can swallow, the patient should be encouraged to drink freely, and, if vomiting follows, so much the better, as this tends to relieve the lungs, which are always greatly congested. Other measures of treatment, and the management of after-consequences, may be most safely left in the hands of the physician.

After what has been said, the means to be adopted for the avoidance of sunstroke will readily suggest themselves. Great care must be taken to preserve intact the function of the skin, and nothing is better for this than frequent bathing, and friction of the surface. Hard labor, in a close, highly-heated atmosphere, or during extreme hot weather, in the sun, should be carefully shunned, and the use of spirits, if previously indulged in, entirely discontinued. The dress should be such as will permit free loss of heat, preferably linen, and on no account should it be so close fitting as to hinder the motions of the chest, neck, or head. A light hat, permitting free circulation of air about the top of the head, is very useful. English troops in India wear light wicker-helmets made of bamboo, and covered with cotton. These permit thorough ventilation of the head, and, according to Dr. Parkes, have diminished the frequency of sunstroke.

SKETCH OF PROFESSOR COFFIN.

FROM Sir Richard Coffin, Knight, who accompanied William the Conqueror to England in 1066, springs the genealogical tree that bears the name of Tristram Coffin, the pioneer owner of the island of Nantucket, whose American descendants have been engaged, to a large extent, in navigation. Of these, and fifth in line of descent from Tristram, is the subject of this sketch.

Prof. JAMES HENRY COFFIN, LL. D., was born in Williamsburg, Mass., on the 6th day of September, 1806. He was, therefore, sixty-six years old at the time of his decease, which occurred February 6, 1873, at Lafayette College, Easton, Pa., where he had long filled the professorship of Mathematics and Astronomy. He graduated at Amherst College in 1828, and the year following established, at Greenfield, Mass., the Fellenberg Manual Labor Institution, which for eight years continued to be one of the rarely successful instances of this system in our country. He subsequently became the Principal of the Ogdensburg (N. Y.) Academy, and, in 1839, a member of the Faculty of Williams College. In 1846 he became Professor of Mathematics in Lafayette College. In the interests of this institution he labored zealously till the close of his life, being rewarded by seeing it rise to its present high rank among our colleges.

As a teacher he was laborious and enthusiastic, and his success was remarkable. He secured the respect and love of his pupils to a degree seldom equalled; but he was also a zealous student in science, and published several valuable works as the results of his researches. Among these are his "Analytical Geometry," and his "Conic Sections," which, at one time, were extensively used as text-books in our colleges. While connected with the Fellenberg Institution, he published two works on book-keeping, that were adopted by the State schools of Massachusetts. He read many valuable papers before the American Association for the Advancement of Science, of which he was, from its organization, a member; and also before the National Academy of Science, for the recent meeting of which he had in preparation an article on the Storm-curve, the object being to show that it was an hyperboloid, the equation of which he had computed.

His chief reputation, in science, was achieved by his researches in the department of meteorology. These were commenced in 1839, while Principal of the Ogdensburg (N. Y.) Academy. He took simultaneous and constant observations of the barometric changes connected with the variations of the wind-vane and with the fall of rain. His instruments were self-registering. Each motion of the vane directed a minute but constant stream of dry sand into some one of 32 stationary hoppers, corresponding in position to as many points of compass. The weight of sand found in the several receptacles below each hopper showed the length of time that the vane had pointed in that direction. The rain-gauge was an inverted cone, having an horizontal surface of 172.8 square inches: the rain falling into it passed down, through an orifice so small that no appreciable evaporation could occur, into a close-fitting can. One inch of rain in depth would, therefore, make $\frac{1}{10}$ of a cubic foot when collected, the weight of which is 100 ounces. Each ounce that the can contained after a storm, consequently, represented $\frac{1}{100}$ of an inch in perpendicular fall. The amount necessary to merely moisten the funnel without precipitation into the can is easily determined as a constant. The results of these observations for the year 1838 were published by Prof. Coffin in the *Meteorological Register*, a monthly journal, of which he issued the first number in January, 1839. It was devoted to the discussion of various phenomena connected with physical science. Though the demand for a periodical of this nature was insufficient to sustain it, it brought into correspondence many who were interested in such subjects. The investigation of rainfall and evaporation had present practical value in being made the basis of the report of the committee of the New York Senate, in 1839–'40, appointed to consider the enlargement of the canal system of the State by the construction of the Genesee Valley Canal. These studies were afterward extended to form the chapter on the climate of the State, published in the "Natural History of New York," in 1845, in which the inquiries took a wider range; and questions of vegeta-

tion, agricultural epochs, the migration of birds, etc., were introduced. A determination was also made of the amount of rise in the thermometer per hour, during the prevalence of winds from the northeast by east to south-southwest, and the unequal corresponding decrease of temperature when the winds were from the northwesterly points of compass.

While at Williams College, Prof. Coffin erected, upon the Greylock peak of Saddle Mountain, at a height of nearly 4,000 feet above the ocean, an observatory, where continuous observations were taken, even through the winter season, when for three months it was impracticable to ascend the peak. In this interval the clock-work faithfully did its entire duty. The anemometer had been changed by substituting for the stream of sand a series of cards half an inch square, laid consecutively on a moving band that deposited one of them every fifteen minutes. Each card being inscribed with the day and hour it represented, when the receptacle marked "North," for example, was examined, all the cards found in it indicated the exact quarter-hour in the past three months when the wind was from that direction. In 1872 he constructed, for the observatory of the Argentine Confederation, at Cordova, a duplicate of this instrument, with improvements by John M. Junkin, M. D., similar to the one in use at Lafayette College.

The "Results of Meteorological Observations for 1854–'59," in two volumes, quarto, 1757 pages, prepared under his supervision, under the auspices of the Smithsonian Institution, constitute a vast fund of condensed material from which to study the climate of North America.

But the great work of Prof. Coffin's life was the development of his theory of the winds, under the auspices of the Smithsonian Institution, the following account of which has been furnished us by Prof. Henry, Secretary of the Institution:

The results of the scientific labors of Prof. Coffin include contributions to astronomy, mathematics, and especially to meteorology. His labors in regard to the latter branch of science commenced immediately after his graduation, and were continued, almost uninterruptedly, until the time of his death. He was early recognized as one of the meteorologists of the country, and, on the establishment of the Smithsonian Institution, he was invited to become one of its collaborators in that line. All the materials which were collected from the observers of the Institution, and from those of the army from 1854 to 1859 inclusive, were placed in his hands for reduction and discussion. This work was conscientiously and thoroughly performed, and the results published in a quarto volume of upward of 1200 pages. In conducting this work, Prof. Coffin engaged the services of some of the students of Lafayette College, and a large number of women. The wages of these computers were paid by an appropriation from Con-

gress, while the services of Prof. Coffin himself, in directing and superintending the whole, were entirely gratuitous.

But the great work to which he owes his celebrity, in all parts of the world, is his treatise on "The Winds of the Northern Hemisphere," published in the "Transactions of the Smithsonian Institution," vol. vi., in 1853. This work had been commenced at least ten years before the date of its publication, a communication having been made in relation to it to the American Association for the Advancement of Science, in 1848.

The materials on which it was based were derived from all accessible sources, including 600 different stations on land, and numerous positions at sea, extending from the equator to the 83d degree of north latitude, the most northerly point ever reached by man, and embracing an aggregate period of over 2,800 years.

The design of the work was to ascertain, as far as possible, the mean direction in which the lower stratum of the air moves in different portions of the Northern Hemisphere, its rate of progress, the modification it undergoes in different months of the year, the amount of deflecting forces, and its relative velocity from different points of the compass. The collection of this material involved an amount of correspondence and bibliographical research which but few would undertake, even with the hope of pecuniary reward, and still fewer for the love of truth, and the acquisition of knowledge for its own sake. But the labor of computation, and discussion of the materials, was an almost Herculean task, to which years of silent and unobtrusive labor were devoted. The work consisted mainly of about 140 quarto tables of figures, with descriptive deductions, and illustrated by maps. Each of these figures is the result of laborious calculations, since the method of determining the velocity and direction of the wind is the same as that employed by the mariner in determining the distance in a straight line, and direction at the end of a given time, from the place of his departure. In this work Prof. Coffin was the first clearly to establish the fact, by accurate comparison of observations, that there are three great zones of winds in the Northern Hemisphere. The first belt is that of the region of the easterly trade-winds, extending northward in the Western Hemisphere to about the 32d degree north latitude, and in Europe to the 42d degree. The second is the great belt around the world of the return-trades, in which the predominant direction is from the west. This extends northward in America to 56°, and in Europe and Asia to about 66° north latitude. Beyond this, principally within the Arctic Circle, is a belt of easterly or northeasterly winds. The common pole of these belts or zones has not the same position as that of the geometrical pole of the earth. It appears to be in latitude 84° and longitude 105° west of Greenwich, and has been denominated by Prof. Coffin the meteorological pole.

These results are in general accordance with the mathematical de-

ductions from the theory of the winds of the globe, which considers them as due to the combined action of the movement produced in the air by the greater heat of the equator, and the rotation of the earth on its axis.

The researches of Prof. Coffin also strikingly exhibit the fact of the influence of the seasons in modifying the direction of the wind, or in producing the results denominated monsoons. Thus, along the eastern coast of North America, as is shown on the maps, the tendency during the summer months of the opposing forces is to lessen the dominant westerly wind, and this effect is noticed even beyond the Mississippi, as well as in the Atlantic Ocean along our coast. The effect is, undoubtedly, due to the change of temperature in the land—the temperature of the ocean remaining nearly the same during the year, while that of the land is greatly increased in summer above the mean, and depressed in winter. From this cause the air will tend to flow toward the centre of the continent from the ocean in summer, and from the same centre toward the ocean in winter.

The results of the investigations of Prof. Coffin have been referred to in all the treatises on meteorology which have appeared since their publication, and they have been employed with other materials as the basis of the wind-charts of the Atlantic and Pacific Oceans, prepared and published by the English Board of Trade.

In attentively studying the result of Prof. Coffin's labors, we cannot but be struck with his conscientious regard for accuracy, and his devotion to truth. In all cases in which the results do not conform to the theory which explains the general phenomena, the discrepancies are fully pointed out; and, where he is unable to suggest an hypothetical cause of the anomaly, he candidly acknowledges his ignorance. In this respect he is an admirable example of a successful investigator, since errors in science as frequently occur from defects of the heart as from those of the head.

After the publication of the work on the winds, he continued to collect materials, at first with a view to an appendix, and finally extended his investigations to the winds of the entire globe. To aid in this enterprise, the Smithsonian Institution placed in his hands all the observations on the winds, which it had obtained from its numerous observers during the twenty years since the system was commenced, together with the observations made by the officers of the army, as well as the extensive series of materials in the various series of transactions of scientific societies of the Old World, obtained through the exchanges of the Institution. This work, for several years past, Prof. Coffin prosecuted with unremitting assiduity during all the intervals which could be spared from his laborious professional duties. Unfortunately, however, he was not spared to complete the work, although it is in such a condition as to be readily finished under the direction of the principal assistant employed by Prof. Coffin. It is

expected that the tables will all be completed during the present summer, and that the printing of the work will be commenced next autumn.

In reviewing what may be called the extra labors of Prof. Coffin, we cannot refrain from endeavoring to impress upon the mind of the general public that men of his character, who do honor to humanity, ought not to be suffered to expend their energies in the drilling of youth in the mere elements of knowledge, and with a compensation not more than sufficient to secure the necessaries of life; that they should be consecrated as officiating priests in the temple of knowledge, be furnished with all the appliances and assistance necessary to the accomplishment of their objects, namely, the extension of the bounds of human thought and of human power.

The premature death of Prof. Coffin is a loss to the world, and, in regard to him, we have to deplore that so much of his valuable life was expended in the drudgery of teaching, which ought to have been devolved upon inferior minds.

DR. JOHN W. FOSTER, the distinguished geologist and ethnologist, of Chicago, died June 29th. He was born at Petersham, Mass., March 4, 1815, and graduated at the Wesleyan University, of Middletown, Conn. He subsequently moved to Ohio, and connected himself with the geological survey of that State. In 1849 he entered upon a geological examination of the Northwest, in company with Messrs. Jackson and Whitney; and the observations they made are embraced in two volumes, entitled "Report on the Geology and Topography of the Lake Superior Land District" (1850–'52). Dr. Foster published an elaborate volume, "The Mississippi Valley," which gave an account of the physical geography, topography, botany, climate, geology, and mineral resources, of that vast and important region of the continent. He was President of the American Association for the Advancement of Science, at its meeting in Salem, in 1869, and has contributed numerous papers to the proceedings of that body and to the Chicago Academy of Sciences. He has been long engaged in the preparation of a work on the "Prehistoric Races of the United States," which was completed and printed, but not yet published, at the time of his death. It is an elegant volume, and a valuable contribution to the subject.

CORRESPONDENCE.

HYDROPHOBIA AN ACTUAL, NOT ALWAYS AN IMAGINARY DISEASE.

To the Editor of the Popular Science Monthly:

NO doubt it is true that many persons have become ill, after being bitten by dogs, under a strong *apprehension* of hydrophobia. But, while scientific medical men ought to be, and mostly are, ready always to study "anew," that is, in view of all new facts, their oldest and most firmly-held opinions, yet some things have been clearly ascertained on this subject—not as matters of opinion, but as *facts:* First, that dogs (and, less often, some other animals) are subject to attacks of rabies, having a period of incubation, after being bitten, averaging, according to Youatt, five or six weeks. Also, every author of standing on the practice of medicine or surgery recognizes the fact that about one in ten of those human beings, of any and all ages, who are bitten by rabid dogs, will be, mostly within a month or six weeks, affected with symptoms entirely peculiar, ending in death in a few days, notwithstanding all the methods of treatment yet devised and used.

But the cases occurring in children are certainly the most convincing. Twenty years ago, I saw such a case, the whole history of which was known to me, in a boy eight years of age. My friend Dr. Lodge, of Montgomery County, Pennsylvania, informs me that, a few years since, he had charge of the case of a child of *five* years of age, some account of which occurs in Gross's standard work on surgery.

The importance of a right popular apprehension of the truth on this subject is considerable. Not only is it necessary that every clearly rabid animal should be killed promptly, and every suspected one fastened up and watched in security, but also that due *measures of prevention* should be resorted to at once, when any one is bitten. These measures (generally known) are, either the removal of the part, when practicable, or thorough *cauterization*. Should the idea become common that there *is no such disease* as hydrophobia in the human subject, as appears to be intimated in the article in your interesting "Miscellany," in THE POPULAR SCIENCE MONTHLY for June, all such precautions are likely to be neglected, at the imminent risk of many lives, which, by means of such measures (if they be resorted to *immediately*), can be protected from this truly terrible malady.

Very respectfully,

HENRY HARTSHORNE.

THE TRANSFUSION OF BLOOD.

To the Editor of the Popular Science Monthly:

THE perusal of the article with the above title, in the April number of your magazine, brings to my mind two or three paragraphs from "Pepys's Diary" bearing on that subject, which may be interesting to your readers. Under date of November 21, 1667, we find: "With Creed to a Tavern, where Dean Wilkins and others: and good discourse; among the rest, of a man that is a little frantic (that hath been a kind of minister, Dr. Wilkins saying that he hath read for him in his church), that is poor and a debauched man, that the college have hired for 20*s.* to have some of the blood of a sheep let into his body; and it is to be done on Saturday next. They purpose to let in about twelve ounces; which, they compute, is what will be let in in a minute's time by a watch." November 30th, we have the sequel: "I was pleased to see the person who had his blood taken out. He speaks well, and did this day give the (Royal) Society a relation thereof in Latin, saying that he finds himself much better since, and as a new man; but he is cracked a little in his head, though he speaks very reasonably, and very well. He had but 20*s.* for his suffering it, and is to have the same again tried upon him; the first sound man that ever had it tried on him in England, and but one that we hear of in France." November 14, 1616, I find: "Dr. Croone told me that, at the meeting at

Gresham College to-night, there was a pretty experiment of the blood of one dog let out (till he died) into the body of another on one side, while all his own run out on the other side. The first died upon the place, and the other very well, and likely to do well. This did give occasion to many pretty wishes, as of the blood of a Quaker to be let into an archbishop [e. g., Laud?] and such like; but as Dr. Croone says, may, if it takes, be of mighty use to man's health, for the amending of bad blood by borrowing from a better body."

W. WOODBRIDGE, M. D.

EDITOR'S TABLE.

SCIENCE IN EDUCATIONAL DISCIPLINE.

WE note a very healthy curiosity on the part of many of our exchanges in regard to the progress of Mr. Spencer's discussion of Sociological Study. Now that he has considered the "Theological Bias," there is much solicitude expressed that he shall not forget the "Scientific Bias." Well, he has not forgotten it. We give his views in the present number of the MONTHLY, and commend them to the careful perusal of our readers. Mr. Spencer's treatment of the subject, however, has important bearings that he does not pursue. Although pointing out the influence of the study of various sciences in forming the mental habits necessary to deal with the single subject of Sociology, he in reality develops the disciplinary value of the sciences in their adaptation to the general work of education.

And the supreme question of education is undoubtedly that of mental discipline. Its primary object is to get the use of the tools of learning—the arts of reading, writing, and elementary computation. So much is indispensable for everybody; but, where education proceeds to its higher work, the next step is the application of the implements to the acquisition of knowledge. Here difficulties arise from its boundless extent. All subjects cannot be studied; whole ranges of them can never be even approached by any single mind; and, as what can be actually acquired is relatively so small, it was long ago seen that the main work of the school must be to form the mind and develop its capacities for effective action in subsequent life. An important truth was here recognized, but its bearing and exact value were far from well understood, and its undue influence led to bad results. For, although the principle is sound, that the chief purpose of education is to cultivate the mental capacities, yet this cannot be done except by means of studies selected for the purpose; and it was a grave mistake to lose sight of the value and adaptation of the knowledge to be gained, however comparatively small might be its amount. Yet such was the result. The staple studies of a liberal education had not been chosen with a view to their special mental influence, and were originally adopted for reasons of utility, because they were suited to the business wants of the professional classes. Yet their supremacy and permanence were defended on the ground of their incomparable merit for discipline. And, when modern studies began to press for increasing recognition in the higher schools, they were resisted on the principle that the acquisition of knowledge was not the object of academic study, but only mental training. The studies in use were defended for their superior claims in this respect, and the sciences were kept out of the schools, or but partially and grudgingly admitted, because they were said to be unsuited for the attainment of discipline. But this is one of the cases in which the truth turns out to be exactly the reverse of

old and established opinion. The studies that have held their supremacy for ages, on the ground of their eminent suitableness for mental discipline, are at last losing their ascendency because of defects in this respect; and the studies which were long resisted because of their alleged unfitness to train the mind, are now coming into wide recognition as the best and indispensable means of attaining this end.

The educational advance here indicated is of the highest significance, for the old scholastic scheme which vaunted its perfect adaptation to the work of mental development was chiefly remarkable because it did not include a single branch of study which brought the mind into direct relations with Nature. It was, in fact, a scholastic curriculum in which Nature was entirely left out, and its discipline could hardly be other than partial and artificial. On the other hand, it now begins to be seen and acknowledged that the completest discipline of the human mind must come from the comprehensive and systematic study of Nature itself. This step is an immense gain to rational culture by putting an end to the old anomaly that the most valuable knowledge for application in life is antagonistic to that required for mental development. It is now perceived that "it would be utterly contrary to the beautiful economy of Nature if one kind of culture were needed for the gaining of information, and another kind were needed as a mental gymnastic. Everywhere throughout creation we find faculties developed through the performance of those functions which it is their office to perform; not through the performance of artificial exercises devised to fit them for these functions."

With the growing study of Nature, and the creation of those perfected forms of knowledge which we call science, the grave defects of the old methods of study have become more and more apparent, and are affirmed with emphasis by men of broad cultivation and the highest intellectual eminence. Mr. Mill shows that logic, the very science by which truth is investigated, was paralyzed for two centuries by the habit, prevailing in the universities, of regarding logical propositions as involving the relations of *ideas* instead of the relations of the *phenomena* of Nature. So long as logic and the connected branches of mental philosophy assumed that the investigation of truth consisted merely in contemplating and handling ideas, little was done in the way of discovery. Mind wrongly trained was barren of valuable results. It was only by the inversion of this procedure, and the adoption of the scientific method of study which brought the mind face to face with natural phenomena and gave it a new discipline, that the great and fruitful truths of modern knowledge have been attained. Dr. Whewell, late Master of Trinity College, in the Cambridge University, and a man of high scholarship, in his various works upon education, protested strongly against the deficiencies of the old system in the matter of discipline, and demanded the larger introduction of the sciences to repair their defects. He said: "The period appears now to have arrived when we may venture, or rather when we are bound to endeavor to include a new class of fundamental ideas in the elementary discipline of the human intellect. This is indispensable if we wish to educe the powers which we know that it possesses, and to enrich it with the wealth which lies within its reach."

In an able lecture by Prof. Helmholtz, just published in this country, "On the Relation of Natural Science to General Science," he considers the several branches of study as exercises for the intellect, and as supplementing each other in that respect. Admitting that a certain kind of discipline is obtained by the study of grammar and philology, he shows that it is radically

defective, and requires scientific culture to correct it. He says: "In proportion as the range of science extends, its system and organization must be improved, and it must inevitably come about that individual students will find themselves compelled to go through a stricter course of training than grammar is in a position to supply. What strikes me in my own experience of students who pass from our classical schools to scientific and medical studies is, first, a certain laxity in the application of strictly universal laws. The grammatical rules, in which they have been exercised, are for the most part followed by long lists of exceptions; accordingly, they are not in the habit of relying implicitly on the certainty of a legitimate deduction from a strictly universal law. Secondly, I find them for the most part too much inclined to trust authority, even in cases where they might form an independent judgment."

Of such criticisms the literature of modern education is full, so that we may say that the traditional culture is now indicted before the world for breaking down at precisely that point in which it has claimed the greatest strength. That the old method of study disciplined the mind was nothing; the question is, What kind of discipline did it afford? All prolonged mental effort in any direction gives power and fixes habit, but the effect may be so narrowing and perverting that the discipline becomes an evil in proportion to its thoroughness. The need and value of scientific studies, as a correction of classical discipline, are now generally admitted; but, before any such correction can be intelligently or effectually made, it is necessary to know what sort of discipline the study of science confers. Science is a comprehensive term; it means various groups of sciences which exercise the intellect in widely different ways. A discipline may be scientific, and still be partial and deficient. We were, therefore, in need of a thorough analysis of the subject, and a statement of what the several sciences are competent to do in the training of the mental faculties. This want has now been supplied by Mr. Spencer.

Obviously the first thing here wanted is a classification of the sciences, and it is equally evident that such an application of it as is here contemplated would become a test of its validity. In a true classification, objects are grouped together which are most alike in characters, and only those sciences which are most similar will call forth like mental activities in their pursuit. Mr. Spencer divides the sciences into three groups: *Abstract* sciences; *Abstract-concrete* sciences; and *Concrete* sciences.

Abstract science is the science of pure relation, with no reference to the nature of the things related. The abstract sciences are logic and mathematics, and they deal with the abstract relations under which all phenomena are presented.

Mr. Spencer holds that space and time, the forms of phenomena, "are contrasted absolutely with the existences disclosed to us in space and time; and that the sciences which deal exclusively with space and time are separated by the profoundest of all distinctions from the sciences which deal with the existences that space and time contain. Space is the abstract of all relations of coexistence; time is the abstract of all relations of sequence. And, dealing, as they do, entirely with the relations of coexistence and sequence in their general or special forms, logic and mathematics form a class of the sciences more widely different from the rest than any of the rest can be from one another." These sciences are, therefore, better suited than any other to establish in the mind "unshakable beliefs in necessities of relation;" and Mr. Spen-

cer points out the unequal values of logic and different branches of mathematics for this purpose.

As the first division takes into account only ideal relations, the second division takes up relations among realities. It includes concrete things, and gives rise to a division which Mr. Spencer, therefore, calls the abstract-concrete sciences. These are mechanics, physics, and chemistry. They deal with the laws of forces as manifested by matter, but when artificially separated from one another. Mechanics, physics, and chemistry have, for their object, to generalize the laws of relation of their several phenomena, when disentangled from those actual conditions of Nature in which they are mutually modified. For example: "In works on mechanics, the laws of motion are expressed without reference to friction and resistance of the medium. Not what motion ever really is, but what it would be, if retarding forces were absent, is asserted. If any retarding force is taken into account, then the effect of this retarding force is alone contemplated: neglecting the other retarding forces." This group of sciences introduces a new order of ideas which call out a different form of mental exercise. They deal with causation, and have great value in giving "distinctness and strength to the consciousness of cause and effect." By familiarizing the mind with numberless simple and separate cases of the action of forces, "they make it impossible to think of any effect as arising without a cause, or any cause as expended without an effect; and they make it impossible to think of an effect out of proportion to its cause, or a cause out of proportion to its effect."

Mr. Spencer's third division comprises what he terms the concrete sciences, or the real, as contrasted with the wholly or partially ideal sciences. They include astronomy, geology, biology, and psychology, which consider phenomena in their totalities or aggregates. These sciences, being far more complex than the preceding, and presenting their various phenomena in combination, are suited to cultivate the synthetical habit of mind, and to familiarize it with complex causation. Mr. Spencer shows that, while the concrete sciences cannot be made to give the mental discipline of the simpler groups, they are indispensable to exercise the mind upon the fundamental conceptions of continuity, complexity, and contingency in causation, and which are of the highest importance in the judgment of common affairs.

The authorities cited above, and which might have been greatly multiplied, establish the fact, beyond cavil, that there is a profound deficiency in the discipline of the current classical system of study; and they all agree that the introduction of science is alone competent to afford a remedy. Mr. Spencer has shown not only how comprehensive and varied is the discipline which the sciences are capable of yielding, but he has pointed out the radical insufficiency of limited portions of science for that complete mental training which it is the object of the higher education to give. In the interests of mental discipline, therefore, we are compelled to demand a reconstruction of the curriculum of "liberal culture," with not merely more of science in it, but with such an organized scheme of scientific studies as will accomplish the end desired.

LITERARY NOTICES.

POPULAR LECTURES ON SCIENTIFIC SUBJECTS. By H. HELMHOLTZ, Professor of Physics in the University of Berlin. Translated by E. ATKINSON, Ph. D., F. C. S., Professor of Experimental Science, Hoff College. With an Introduction by Prof. TYNDALL. New York: D. Appleton & Co., 1873.

THIS is, in several respects, the most important scientific publication of the sea-

son, its interest being due not alone to its valuable contents, but quite as much to the form in which they have been put by their illustrious author. When the present MONTHLY was started, surprise was expressed in various quarters at the broad scope of its discussions, which it was said went far beyond the legitimate meaning of our title. Science being considered as a kind of tough and forbidding knowledge belonging to laboratories, observatories, and apothecaries' shops, popular science was regarded as the same kind of knowledge loosely stated in common language. At the outset we rejected this view as narrow and false, holding that science, instead of pertaining to certain things, consists in a method of knowing, which applies to all things that can be known, and that popular science must be equally comprehensive. Science itself being progressive, its great army of workers is constantly engaged in extending and correcting it by numberless processes of original investigation, while it is the office of popular science to bring its conclusions, applications, and results, into the sphere of common thought. Learned men long neglected the duty they owed to the public to clothe the result of their labors in authorized and acceptable forms for general use, and the consequence was that this work was done by incompetent hands, and degenerated into mere amusement and recreation; but, with the progress of liberal opinion, the diffusion of education, and increasing respect for the rights and welfare of the people, eminent men of science have turned their attention seriously to the task of embodying their ideas in popular form.

In his introduction to the present volume, Prof. Tyndall remarks: "One evening during my residence in Berlin, my friend Dr. Du Bois-Reymond put a pamphlet in my hands, remarking that it was the 'production of the first head in Europe since the death of Jacobi,' and that 'it ought to be translated into English.'" That "first head in Europe" was on the shoulders of Helmholtz, and the pamphlet was his celebrated essay on the "Interaction of the Natural Forces," which has been extensively circulated in this country, and is one of the most elegant and popular expositions of the doctrine of the "Conservation of Force" that has appeared in any language. The first complete work of Prof. Helmholtz in English is the volume now issued, consisting of popular lectures on scientific subjects. Speaking of these lectures in his preface, the author says: "If I may claim that they have any leading thought, it would be that I have endeavored to illustrate the essence and the import of natural laws and their relation to the mental activity of man. This seems to me the chief interest and the chief need in lectures before a public whose education has been mainly literary." It is gratifying to note that this statement of the chief aim of popular science entirely coincides with the view presented in the prospectus of THE POPULAR SCIENCE MONTHLY. It is not the illiterate that are to be addressed, but the classes that have received such cultivation as the prevailing educational system affords, while the development and illustration of natural laws in their bearing upon the higher nature and elements of man is the ultimate and most important end to be attained.

HERMANN LUDWIG FERDINAND HELMHOLTZ was born at Potsdam in 1821. He studied medicine, and was at first military physician and afterward assistant at the Astronomical Museum at Berlin in 1848. From 1849 to 1852 he was Professor of Physiology in the University of Königsberg. He became Professor of Physiology at the University of Bonn in 1855, and in 1858 accepted the physiological chair in the University of Heidelberg. He is now reëstablished in Berlin as professor in the university of that city. Prof. Helmholtz has attained a recognized preëminence in three great departments of knowledge—physiology, physics, and mathematics. He began with the study of physiology, but, finding that to be dependent upon physics, he proceeded to master the physical field. But here, finding again that physics depends upon mathematics, he pushed on to the conquest of this department of science. His great works are on "Physiological Optics" and "The Physiology of Audition," and, by his thorough acquaintance with physics and mathematics, he has greatly enriched and extended our knowledge of the science of these higher senses. Prof. Helmholtz's intellect is characterized by great breadth and

synthetic grasp, which leads him to take large views, and treat the subjects he enters upen with comprehensiveness. The opening and closing papers of the present volume—the first, "On the Relation of Natural Science to Science in General," and the last, "On the Aim and Progress of Physical Science"—are admirable examples of this broad judicial treatment of the subjects discussed. His statement of the reactions of science and philosophy in Germany, and the influence of the German universities upon contemporary thought, in the first paper, is especially admirable. The volume also contains very able articles upon his special subjects of investigation—one "On the Physiological Causes of Harmony in Music," and another elaborate paper, in three parts, "On the Recent Progress of the Theory of Vision." There is also a very interesting lecture "On Goethe's Scientific Researches," and an elaborate discussion of glacial phenomena. Two papers are also given "On the Interaction and Conservation of Forces," a subject which Prof. Helmholtz has pursued independently, and which in these expositions is presented in its fundamental principles. Numerous illustrations enhance the instructiveness of the volume, which, though compactly written, is still remarkably clear in its explanations. Prof. Helmholtz is an eminent master of the art of statement, but, as his thoughts appear in a foreign language, the force and finish of the original composition are not to be looked for. Yet the several translations of this volume by Professors Eve, Ellis, Atkinson, Tyndall, and Drs. Flight and Pye-Smith, have been made with great care, so that the work is as attractive and readable in style as it is solid and instructive in its thought. We commend this book to all who are interested in the higher scientific problems of the age, as treated by one of its master-minds.

THE MINERAL SPRINGS OF THE UNITED STATES AND CANADA, with Analyses and Notes of the Prominent Spas of Europe, and a List of Sea-side Resorts. By GEORGE E. WALTON, M. D. New York: D. Appleton & Co.

THE author of this work seems at first to have been sorely perplexed as to whether there are or are not any medicinal virtues in mineral waters. The public is inclined to be credulous in regard to their remedial uses, and the medical profession is inclined to be skeptical about them. In point of fact, great numbers of people with divers ailments seek the mineral fountains of various localities, and use them very much at hap-hazard. At the same time he says that, while the American profession is inclined to be incredulous as to the medical services of these springs, eminent European physicians, such as Trousseau and Niemeyer, assign an important place to mineral waters in the treatment of many chronic diseases. In this unsatisfactory state of opinion, Dr. Walton entered systematically upon the inquiry as to the remedial uses of the mineral waters of the United States and Canada, and in the volume now printed he has endeavored to arrange all the known facts concerning them in such a manner that they shall be readily accessible, and serve to guide the reader in selecting such as shall be best adapted to his own wants: "For this purpose he has consulted the best European authors, their conclusions being drawn from hundreds of years of laborious investigation of the spas of Germany, France, Switzerland, and Italy. It has been interesting, in the course of this study, to note how closely the conclusions drawn by them, concerning the action of different classes of waters, agree with the observations made at springs in this country independent of any knowledge of foreign research. The portion relating to the springs of the United States is the result of a selection of credible evidence regarding them gained by correspondence and personal observation."

After some preliminary chapters on the nature, classification, and chemical constituents of mineral waters and their relations to various organs and diseases, Dr. Walton considers the springs of the country under the heads of "Saline Waters," "Sulphur Waters," "Chalybeate Waters," "Purgative Waters," "Calcic Waters," and "Thermal Waters," and the resources of the whole country are then given in respect to mineral waters having these various properties. Of all the localities in the United States or Canada, Saratoga is the most eminent for the extent and variety of

its fountains. Dr. Walton gives the analysis of 15 of its springs, tabulating no less than 23 of their constituents held in solution; and of their general character he remarks:

"The principal constituents of these waters are chloride of sodium, the alkaline carbonates, and carbonic-acid gas, hence they may be termed *alkaline-saline* waters, of which the famed Seltzer Spring of Nassau is a typical example. In point of merit, the Saratoga waters equal, if they do not surpass, any of the kind in the world. The large amount of carbonic acid which they contain, and the favorable combination of ingredients, render them very easy of digestion, and, to most persons, exceedingly pleasant to the taste. Many wonder why it is that during the hot months of the year such numbers crowd to Saratoga, thinking it only a whim of fashion; but, aside from social attractions or amusements, there is a positive value in the water, and pleasure in drinking it, which will always attract multitudes to its fountains. These waters are especially adapted to cases of *dyspepsia;* those depending on high living and an engorged condition of the abdominal viscera are peculiarly subject to their beneficial influence. In *jaundice*, depending on catarrh of the biliary ducts, they are curative, and they would undoubtedly prove beneficial in cases of *gall-stones* with a tendency to their continual formation and passage. In *engorgement of the liver*, and all conditions of abdominal plethora, they are a valuable remedy."

Of these waters which "equal, if they do not surpass, any thing of the kind in the world," some have been long tried, and others are new discoveries. The celebrated Congress Spring has had a world-wide reputation from early in the century as one of the most valuable of mineral waters. The Hathorn Spring has only been known since 1868, but it furnishes an excellent water, which is coming rapidly into favor. Dr. Walton says: "In taste and general character, it resembles the Congress water, but is stronger." These waters "bottle well," that is, undergo no change by precipitation, and are thus available for transportation to multitudes who cannot visit the springs.

The Geyser Spring, which also yields a strong and excellent water, has lately attracted much attention. Our author says of it:

"This spring is one of the curiosities of Saratoga. It was discovered in February, 1870. During a dull season, the owners of a bolt-factory, in which it is located, concluded to bore for mineral water. They chose the cellar of the factory in which to operate. Having sunk a tube to the depth of 154 feet, the water burst forth in such a volume as to entirely inundate the premises. On attaching a tube of smaller calibre, the water was projected to the height of 22 feet, and continues spouting forth in an intermittent stream. It is highly charged with carbonic-acid gas, so much so that, when drawn from a faucet into a glass, it foams up like soda-water. It is also exceedingly rich in saline constituents."

SPENCER'S DESCRIPTIVE SOCIOLOGY.—Messrs. Williams & Norgate have just issued the prospectus of a unique and most elaborate work by Mr. Herbert Spencer, consisting to a large extent of the tabulated material which he has accumulated for his "Principles of Sociology." In preparation for the latter work, requiring as bases of induction large accumulations of data, fitly arranged for comparison, Mr. Herbert Spencer, some five years ago, commenced the collection and organization of facts presented by societies of different types, past and present. Though this classified compilation of materials was entered upon slowly to facilitate his own work, yet, after having brought the mode of classification to a satisfactory form, and after having had some of the tables filled up, the results appeared likely to be of such value that Mr. Spencer decided to have the undertaking executed with a view to publication: the facts collected and arranged for easy reference and convenient study of their relations, being so presented, apart from hypotheses, as to aid all students of Social Science in testing such conclusions as they have drawn and in drawing others. The work consists of three large divisions. Each comprises a set of tables exhibiting the facts as abstracted and classified, and a mass of quotations and abridged extracts,

otherwise classified, on which the statements contained in the tables are based. The condensed statements, arranged after a uniform manner, give at one view, in each table or succession of tables, the phenomena of all orders which each society presents—constitute an account of its morphology, its physiology, and (if a society having a known history) its development. On the other hand, the collected extracts, serving as authorities for the statements in the tables, are (or, rather, will be, when the work is complete) classified primarily according to the kinds of phenomena to which they refer, and secondarily according to the societies exhibiting these phenomena; so that each kind of phenomenon, as it is displayed in all societies, may be separately studied with convenience. The three divisions, each thus constituted, comprehend three groups of societies: 1. *Uncivilized Societies*; 2. *Civilized Societies—Extinct or Decayed*; 3. *Civilized Societies—Recent or still Flourishing*. Several sample tables have been sent us, and as a specimen of the classifactory headings under which the immense array of facts are grouped, we shall give those belonging to Table IX. of Division I. ("Uncivilized Races"), the Sandwich-Islanders, one of the Malayo-Polynesian Races. First are given their Inorganic Environment (Climate, Surface); Organic Environment (Vegetal, Animal); Sociological Environment (adjacent tribes), Physical, Emotional, and Intellectual Characters. Then follow the tables, divided into Structural and Functional, each of which is subdivided into Operative and Regulative. The Structural Operative is again subdivided into Operative and Regulative; the Structural Regulative is subdivided into Political (*Civil* [Domestic (Marital, Filial), Public], *Military*), Ecclesiastical, and Ceremonial (*Mutilations, Funeral Rites, Laws of Intercourse, Habits, and Customs*). Under Functional, the Regulative is subdivided into Sentiments (*Æsthetic, Moral*), Ideas (*Superstitions, Knowledge*), and Language; the Operative into Processes (*Distribution, Exchange, Production, Arts, Rearing, etc.*), and Products (*Land - Works, Habitations*, etc., *Food, Clothing, Implements, Weapons, Æsthetic Products*). Under each final subdivision ample details are given. The value of such a work to all students of sociology, and of mankind generally, will be inestimable.—*Nature.*

INTRODUCTION TO CHEMICAL PHYSICS, DESIGNED FOR THE USE OF ACADEMIES, HIGH-SCHOOLS, AND COLLEGES. By T. R. PYNCHON, M. A., Professor of Chemistry and the Natural Sciences in Trinity College, Hartford. New York: D. Van Nostrand.

THE principle of subdivision of labor, upon which our civilization rests, is nowhere more marked than in education. As knowledge extends, and greater thoroughness of study is demanded, science inevitably becomes specialized. A few years ago, two or three introductory chapters on the physics of the subject were prefixed to the treatises on chemistry: now an independent volume is required for the purpose. Miller's "Chemical Physics" is part of his encyclopædic work upon chemical science; but Prof. Pynchon's book is a complete treatise upon the subject, independently presented. The author considers the intimate bearings of heat, light, and electricity, upon the production of chemical phenomena, and his exposition is so full that it not only meets the wants of the higher educational institutions, but will prove equally useful as a guide for manufacturers and practical men. We are glad to see that this work is well appreciated abroad. The London *Mining Journal*, in a very commendatory review, epitomizes its contents as follows: "The history of chemistry is briefly sketched, and reference is made to the fundamental principles of the science, to the apparatus used, to the constitution of some of the most important chemical compounds, to the chemical agents—heat, light, and electricity—and why they are called imponderables, and to other similar elementary matters, a knowledge of which is required for the more profitable study of the succeeding chapters. The chapter on the first chemical agent—heat—is as complete a treatise on the subject as is found in the best college text-books devoted to the subject, and, although concise, the style is by no means uninteresting; the diffusion of heat-expansion, liquefaction, ebullition, evaporation, specific heat, sources of heat, nature of heat, are each treated of, the explanations being rendered particularly clear by the ad-

mirable illustrations by which they are accompanied. Light and electricity are dealt with in an equally complete and satisfactory manner, ample details being given with regard to the nature of light, its sources, reflection, refraction, the solar spectrum, spectrum analysis, the effect of light, and the relations of light and heat; while in the chapter upon electricity there are very full sections upon statistical and galvanic electricity, electro-magnetism, magneto-, thermo-, and animal electricity, and the relations which the several chemical agents bear to each other."

FIFTH ANNUAL REPORT ON THE NOXIOUS, BENEFICIAL AND OTHER INSECTS OF THE STATE OF MISSOURI. BY CHARLES V. RILEY, State Entomologist. 1873.

THAT abundance of correct information about the habits of noxious insects should be diffused among farmers is a thing of capital importance. Many insect-pests, which in former times ravaged the fields and orchards with impunity, are now easily held in check, or exterminated, owing to the enlarged knowledge derived from the researches of scientific entomologists. For instance, after it is once known that the parent Hessian fly makes its first appearance in the latitude of Missouri, about the beginning of September, and usually disappears before the end of that month, the prudent farmer will preserve his grain from the attacks of that destroyer by deferring his planting till October. In like manner, the army worm may be defeated by burning up her eggs with the grass-stalks in which they are deposited. Or we may enlist in our service the natural enemies of the various insect-pests, such as birds, toads, snakes. But their greatest foes are "those of their own household," predaceous or cannibal and parasitic insects. The study of the habits of these insect allies and insect enemies of the husbandman is the occupation of the practical entomologist. The importance of entomological research is now more generally recognized than it was a few years ago, when Dr. Asa Fitch, of New York, was the only State entomologist in the Union. New York, it is true, no longer employs an entomologist, having very unwisely abolished the office two years ago. Other States, however, have instituted the office, and their example is likely to be imitated throughout the Union. The States at present employing entomologists are Massachusetts, Connecticut, Illinois, and Missouri, and Mr. Townsend Glover is attached to the National Department of Agriculture, in the same capacity.

Mr. Riley's very able report is in itself perfectly satisfactory evidence of the value of such studies.

We are pleased to see incorporated with the report a succinct treatise on entomology, intended to give the intelligent farmer an easy introduction to the science.

EIGHTEENTH ANNUAL REPORT OF THE BOARD OF DIRECTORS OF THE ST. LOUIS PUBLIC SCHOOLS, for the Year ending August 1, 1872. With Appendix; pp. 319.

THIS report contains a good deal of important matter that has a more than local value. Besides many instructive details relating to the management of the St. Louis schools, their accomplished superintendent, Mr. W. T. Harris, gives us his views on grading and classification in a system of schools, on the course of study for the public school best suited to modern requirements, and on the important subject of school discipline. On the practice of whipping in schools, he quotes from Superintendent Monteith, as follows: "The indiscriminate use of the whip in school is a practice which is to be condemned as barbarous, cruel, and wicked. It is a wonder that society is so indulgent toward that which, if applied to animals instead of children, would not be tolerated for a moment. I regret to say it, but it is true, that a 'society for the prevention of cruelty to children' could find work for humane hands in many Missouri schools. The case is aggravated when we consider, further, that about two-thirds of the whippings which school-children receive are inflicted for offences for which they are in no way responsible. The crimes they commit, upon which pedagogical vengeance is wreaked, when stripped of the color given to them by unmeaning and senseless rules, are simply the crimes of being a boy and being a girl. They are too often crimes which are incited by bad air, cold feet and shoulders, overwork, and long confinement. They are crimes which the parents of these same children are accustomed to excuse in

themselves, when they sit in church, by the dulness or length of the sermon, or other circumstances that offend against Nature, and which they sometimes soothe with fennel or hartshorn, or by changing of position, and not seldom with sleep. When children know they are not really deserving of punishment, the effect of whipping is to deaden the moral sensibilities, diminish self-respect, and render young natures rude, reckless, and desperate."

The report proper closes with a summarized statement of the more important features of the St. Louis school system, which, both for the intelligent care with which it is directed, and the excellent results attained, is worthy of the consideration of educators generally.

REPORT ON A TOPOGRAPHICAL SURVEY OF THE ADIRONDACK WILDERNESS OF NEW YORK. By VERPLANCK COLVIN. Albany, 1873. The Argus Company, Printers.

THIS is an important contribution to the geography of the State of New York. All the maps of the Adirondack region hitherto published abound in inaccuracies, which are here, for the first time, authoritatively corrected. Even so prominent a landmark as Mount Marcy, the highest mountain of the State, is, in the usual maps, located miles distant from its true place. When a map of the Wilderness is constructed on the data of Mr. Colvin's survey, it will indicate a multitude of great streams, lakes, and mountain elevations, quite ignored by the map-makers. With regard to the future of the Wilderness, Mr. Colvin thinks that the whole water-shed of the Hudson, within the limits of the Adirondack region, should be preserved in its present condition, as a forest farm, and as a source of water-supply for the cities and great towns on the Hudson, from Troy to New York and Brooklyn.

MISCELLANY.

Fossil Monkeys.—With the title "On the Primitive Types of the Orders of Mammalia Educabilia," Prof. E. D. Cope recently read a very remarkable paper before the American Philosophical Society. The professor referred to a previous description, by himself, of certain fossil remains under the name *Anaptomorphus æmulus*, in which he pointed out similarities of the teeth and other parts to like parts in monkeys and man. He also quoted Prof. O. C. Marsh as saying that three fossil genera, previously described by himself, were all referable to the Quadrumana, or monkeys, saying that "they have the principal parts of the skeleton much as in some of the lemurs," the lowest of the monkey race. Some fossil remains, previously described by Prof. Cope, were referred to a genus *Tomitherium*, but with no suggestion as to the order to which they might belong. A reëxamination of this genus has caused it to be referred to the Quadrumana. A remarkable feature in the osteology of this genus is, the relationship shown also to the Coati (*Nasua*). "The first impression derived from the appearance of the lower jaw and dentition, and from the humerus, is that of an ally of the Coati (*Nasua*). The humerus, indeed, is almost a fac-simile of that of *Nasua*. . . A comparison with *Nasua* reveals no distant affinity." The fossil remains of these ancient monkeys were obtained in Eocene strata in the Bridger beds on Black's Fork, Wyoming, and already some seven species are described.

As an example of remarkable scientific prescience, as regards this monkey-cousinship of the *Nasua*, or Coati-Mondi, we give the following foot-note on page six of this interesting paper: "Dr. Lockwood, of Rutgers College, in a recent number of THE POPULAR SCIENCE MONTHLY, expressed serious suspicions of the quadrumanous relationships of the Coati, little thinking at the time that the specimens to confirm his view were, at that moment, in the hands of palæontologists." It is also worthy of mention that Prof. Lockwood's singular induction was worked out of psychological considerations, he stating that the material basis was not at hand, although he insisted that such must exist. Results like the above cannot but give confidence in the processes of the science of comparative anatomy.

Light-Waves and Sound-Waves.—A curious instance of the analogies of light and sound is given in the *Medical Times*, from a German medical journal. Two brothers, named Nussbaumer, are said to receive vis-

ual impressions from sounds. When a certain note is struck upon the piano, the brothers at once have a sensation of a certain corresponding color, which is not, however, identical for both. Thus the note which produces in the one the impression of dark Prussian blue, produces in the other that of dark yellow. They do not, however, perceive all colors on occasion of hearing sounds. One of the brothers has sensations of yellow, brown, and violet, most frequently; while blue, yellow, and brown, are most frequent with the other. One of them never has the sensations of red, green, black, or white, awakened by musical notes, though on one occasion he says that, suddenly hearing a noise from the filing of a saw, he had the sensation of green. No doubt it is very difficult to be secure against deception in such a matter as this; but we may add that Prof. Brühl, of Vienna, after thorough investigation, is satisfied that there is no fraud.

Meteorological Observations in the Upper Atmosphere.—We take, from the Proceedings of the French Academy of Sciences, the following interesting account of meteorological observations made by M. G. Tissandier during a balloon-ascension in the month of February last: Six gentlemen accompanied M. Tissandier on his aërial voyage. The balloon, whose capacity was 2,000 cubic metres, was filled with illuminating gas. The ascent was made from the city of Paris, and the voyagers soon found themselves at an altitude of 1,200 metres, and enveloped in a dense layer of cloud. Having risen above this stratum of cloud, they entered a region where the sun's rays were intensely bright, and the heavens of a deep blue. For about three hours they sailed at an elevation of about 400 metres above the clouds. The shadow of the balloon, as it fell on this ocean of vapor, was very remarkable. At an elevation of 1,350 metres the shadow of the balloon itself had no halo, though one was visible around the shadow of the boat. At 1,700 metres the balloon's shadow was surrounded with rings of rainbow hues. Again, and at the same elevation, there appeared three distinct concentric halos. In all cases the violet was on the inner and the red on the outer side of the halos, but the blue and the orange colors were most clearly visible.

The temperature was very high, being 17.5° Cent., and the sun's rays so hot as to burn the face. The greatest altitude attained was 2,000 metres. As the balloonists descended through the cloud, a copper wire suspended from the boat gave strong indications of electricity. On reaching 1,200 metres, where the cloud was densest, the voyagers were unable to see the balloon above them, and were chilled by the cold, the thermometer showing 2° Cent. The copper wire gave out vivid sparks, and was quickly coated with ice-crystals, which glistened like diamonds. Similar crystals formed on the boat, and on the clothes and beards of the voyagers.

The descent was made at Montireau, distant 120 kilometres from Paris. Time, 3 hours and 45 minutes. M. Tissandier thinks that the dense opaline cloud through which he passed is made up of ice-crystals. The paper by Mohr, in THE POPULAR SCIENCE MONTHLY for May, shows that vapors can resist crystallization at a far lower temperature than 2° Cent.

Social Relations of Ants.—At the Congress of Swiss Naturalists, which assembled in August of last year at Friburg, Auguste Forel read an address upon the "Social Relations of Various Species of Ants." A nest is sometimes occupied by a community belonging to one species, sometimes by a community made up of two or more species, but all have the three classes of males, females, and workers. In a mixed community there will sometimes be found slaves—that is, workers of a different species made captive while still in the cocoon. When these emerge from their silken envelope, they become the friends and willing thralls of their captors, as though such were their natural destiny. A mixed community embraces all three sexes of the captor species, but only workers, or neuters, of the captive. The *Polyergus rufescens* and the *Formica sanguinea* both make slaves of the *Formica fusca*. The *Polyergus* is extremely indolent, but the *F. sanguinea* assists his slaves in their work.

There are certain species of ants which live by the labor of others without enslav-

ing them. To this class belongs the *Anergates atratulus*, a species which have no workers, but which, both males and females alike, live in company with the workers of the *Tetramorium cæspitum*, and are tended by these latter, though the terms on which the association is formed are not known. The *Strongylognathus testaceus* also lives by the charity of the *Tetramorium*. But the author has discovered a species of *Strongylognathus* having true slaves.

Then there are mixed communities, where two species which usually live separately, lead a life in common; but this is a thing of very rare occurrence, and but little investigated. M. Forel has found ants' nests inhabited by the *Formica truncicola* and the *F. fusca*, by the *Tapinoma erraticum*, and the *Bothryomyrmex*, etc. On the other hand, he has also met with communities of the *F. sanguinea*, without slaves.

Inherited Traces of Surgical Operations.—In his fifth lecture on "Eggs," published by the *Tribune* of April 26th, Prof. Agassiz has the following on the transmission of individual peculiarities produced by surgical operations: "But, while the office of inheritance is to preserve typical features, its power to transmit individual peculiarities is also wonderful. My friend Dr. Brown-Séquard, who has made more experiments among animals than any man living, continuing them upon successive generations, and ascertaining what diseases may be transmitted, has stated facts to me which almost defy belief. These facts are unpublished. I will give a few of them. He has found that the disease of epilepsy can be induced in guinea-pigs by certain operations, and that this disease, being so introduced into the system, may be transmitted from generation to generation, and thus become hereditary. Where such operations have produced malformations of the skin, as is often the case, these also have been transmitted; or, where the paws have been affected by such operations, the peculiarity has been also transmitted. Malformation produced by these experiments as a disease during the life of a parent has been passed down to the offspring, and even habits arising from disease have been inherited in the same way. In one such case the peculiarity existed in the female; in another it was produced in the male. In the latter instance the male transmitted its own diseased condition to another generation through a healthy female. More than this, the female through whom these diseased descendants had been produced eventually became herself diseased in the same manner as the male. These facts have a fearful significance. With reference to the process, the subtle influence by which such results are produced, we must be silent for the present, since we cannot explain or understand it. All that we know is, that a material combination takes place which enables us to say that these individual peculiarities are sifted through the egg of the female and the spermatic particles of the male, and may reappear in their progeny."

Clay-eaters.—The Agmara Indians, inhabiting the shores of lake Titicaca, and the lofty plateau of the Andes, find the struggle for existence hard, at an altitude of more than 11,000 feet above the sea-level. Their principal articles of food are *quinoa*, a coarse grain resembling rice, and potatoes, of which tuber their country is the original home. The difficulty of boiling food at so great an altitude necessitates the previous maceration of all articles intended to be so cooked. The potato is, therefore, prepared for storing and use by exposing it to the frost; then it is placed in water, and stamped into a paste; all the soluble matter is washed out, and the starchy and farinaceous substance alone remains. This is called *chuno*, and it is made into a nutritious though insipid soup. The Agmaras use clay as an article of food, mixing it with *quinoa*. The clay they use is of a whitish color, and rather gritty. Careful analysis shows that it contains no organic matter, and therefore it must be used merely for the purpose of producing a satisfactory though delusive distention of the stomach.

The Faculty of Direction.—It will be remembered that, in the course of the discussion as to hereditary antipathy, a side question was introduced by Mr. Wallace, namely, the faculty possessed by certain

animals whereby they are infallibly guided on their return homeward from distant places. Mr. Wallace thinks that this faculty is, in dogs at least, simply a very acute sense of smell. According to him, the dog "takes notes by the way" of the various odors he passes through, and finds his way back by taking the links of this chain in reversed order. But this explanation is open to very serious difficulties, and Mr. Darwin's simpler theory will appear far preferable.

Indeed, Mr. Wallace's theory seems hardly broad enough to account for more than a very inconsiderable fraction of the phenomena which it is proposed to explain. For dogs, cats, horses, and the like, it may be good enough, until a better theory is found. But what possible application could it have to such a case as the following, which is given by Mr. Edward W. Cox, on the high authority of Mr. Robert Fox, of Falmouth? "The fishermen of Falmouth," writes Mr. Cox, "catch their crabs off the Lizard Rocks, and they are brought into the harbor at Falmouth alive, and impounded in a box for sale, the shells being branded with marks by which every man knows his own fish. The place where the box is sunk is four miles from the entrance to the harbor, and that is above seven miles from the place where they are caught. One of these boxes was broken; the branded crabs escaped, and two or three days afterward they were caught again by the fishermen at the Lizard Rocks. They had been carried to Falmouth in a boat. To regain their home they had first to find their way to the mouth of the harbor, and, when there, how did they know whether to steer to the right or to the left, and to travel seven miles to their native rocks?"

It is unphilosophical to set up many different hypotheses, where one would answer. For this reason we are inclined to accept Mr Darwin's explanation of the phenomenon in question, rather than Mr. Wallace's. Mr. Darwin, it will be seen, aims at bringing all the phenomena under one general law, that of a Faculty of Direction, as it may be called. In confirmation of this hypothesis, the veteran naturalist quotes from Von Wrangell's account of his expedition to North Siberia, as to the "wonderful manner in which the natives kept a true course toward a particular spot, while passing for a considerable distance through hummocky ice, with incessant changes of direction, and with no guide in the heavens, or on the frozen sea." Even with the aid of a compass, an experienced surveyor in Von Wrangell's party failed to do what these savages easily effected. Mr. Darwin says the Siberians keep a sort of "dead reckoning" of their course, correcting their deviations partly by eyesight, partly also, perhaps, by a sense of muscular movement, as some men can, even with bandaged eyes, proceed for a short distance in a straight line, turn at right angles, or even back again. Some persons are "turned around," as we say, far more easily than others. Such persons would very easily lose their way, were they to attempt traversing an extensive forest, for instance. Mr. Darwin is inclined to think that some part of the brain is "specialized for the function of direction." If that is the case, it is very natural to suppose that this specialization may be more marked in beasts and savages than in civilized man, as the former have more constant need to exercise the faculty of direction than the latter. Mr. Darwin closes his communication on this subject by citing a case from Audubon, where the faculty of direction was egregiously at fault. The great ornithologist kept a pinioned wild-goose in confinement, and, when the time for migrating came, the bird escaped. Instead of proceeding due southward, as it should have done, the poor creature began its long journey on foot, travelling due northward, exactly the wrong direction.

Habits of the Porpoise.—The behavior of the porpoise in the Brighton (England) Aquarium has been studied with warm interest, by Mr. Henry Lee, F. L. S., who communicates to *Land and Water* an interesting account of his observations. Mr. Lee had previously enjoyed frequent opportunities of watching the porpoise at sea, whether from the bow of a steamer, or over the gunwale of a boat, but an uninterrupted, broadside view of all its movements was, for him, "a new, delightful, heart-stirring sight, and one often longed for." He observed that the tail, with its flat blade spread out

horizontally, is the only propelling instrument possessed by the animal. Even when the creature is in rapid motion, the front fins hang straight down from the sides, and come into play only when it wishes to change its course, or to rise to the surface for the purpose of "blowing." For the latter object, both fins are raised toward an horizontal position, the action of the tail is stopped, and, with the impetus previously gained, the porpoise soars gently to the surface; there, the valve of the blow-hole opens, the breath escapes with a sound between a deep sigh and a quiet puff, and, without the slightest pause, the animal descends again.

The new porpoise at Brighton is four feet six inches in length. The tank in which it is kept is 102 feet long, so that the beast has a very fair opportunity to exhibit its paces. The whole of the first day it cantered incessantly from end to end of the tank, keeping usually at a depth of about three feet, and rising to blow every 15 or 20 seconds. It was very timid, shying at every movement among the spectators. At night, it showed a partiality for gas-light, restricting its movements to the end of the tank that was illuminated. The second day the creature was so tame that it would take food from the hand, dart off with it, and come back for more. When it catches a fish, it seizes it by the middle of the body, holds it there for a second, as if pressing its teeth into it, to make it flexible, and then swallows it at a gulp, without any effort to bolt it head-foremost. "The pretty creature," continues Mr. Lee, "has a nice, good-natured face, in which I fancy I can often read an expression of pleasure and animation, and is as full of fun and frolic as a Newfoundland pup, galloping along something like a dog after a stick, and tossing up its tail with a romping kick, as a skittish colt throws up its heels in play. If it lives, as I hope it will, it will probably become as tame and docile as a seal; for the porpoise is a very intelligent animal. It has a large brain, and acute sensibility."

Persistence of Cholera in Central Europe.—It would appear as if Asiatic cholera had become naturalized in Central Europe. For a few years past the disease has prevailed to a greater or less extent in the Austrian dominions, and the following notes, taken from the London *Times*, will show its movements since the beginning of the present year. At that time the disease existed in numerous localities of Galicia and Silesia, and in a few places in Moravia and Hungary. It was increasing in the city of Lemberg, and, though declining in Buda-Pesth, had not disappeared. During the month of January it invaded several new localities in Hungary, Silesia, Moravia, and Bohemia. During February the disease still continued in the districts just referred to, and lingered in Buda. The garrison of the latter city suffered from a serious outbreak during the last week of January and the first week of February.

The cessation of cholera on the Upper Nile is reported. Its ravages during the last half of 1872 extended over the entire region bounded east and west by the Red Sea and the Desert, and between Kassala, in the north, and Korosko, in the south. The questions of the internal sanitary condition of Persia, and the recent prevalence of plague and frequently-recurring epidemic of cholera in that country, are about to be submitted to a sanitary commission appointed by the European powers, Persia, and Turkey. It is admitted that, so long as the sanitary condition of Persia remains what it is, Europe will continue to be visited by this scourge. The recent outbreak of plague in the Shah's dominions seriously endangered the Ottoman provinces of Asia, and it is at the instance of the Porte that the European powers now demand that the internal sanitary state of Persia be improved. This is a matter that very nearly concerns us, even on this side of the Atlantic, and it is to be hoped that the commission will perform its work thoroughly. Religious scruples and antiquated customs will make resistance, as a matter of course; but the civilized world cannot afford to see its population decimated, simply because unwashed devotees will insist on making their unwholesome pilgrimages. In a country where only a few years ago the government put a stop to corpse-caravans, the commission is sure to have enough to do. It was only in 1867 that a stop was put to the popular custom of transporting, on the backs of camels and mules, one or two hun-

dred putrefying corpses at a time to certain holy places, often distant thirty or forty days' travel.

Sponges.—Naturalists are now generally agreed in classing the sponge with animals, but place it in the very lowest rank of the *Protozoa*, abutting on the vegetable kingdom. Like a plant, the sponge grows on rocks or other substances in water, being often found attached to the shells of living crustaceans. It consists of a gelatinous substance called *sarcode*, and of a framework made up of horny, elastic fibres (*keratose*), or of calcareous or siliceous spicules. The keratose is the sponge of commerce, and its value depends upon the elasticity and compressibility of its fibres.

The sarcode is sometimes represented to be an amorphous mass of glairy substance, but accurate observation with the microscope shows, according to Huxley, that it is constituted as follows: There is, first, an external layer, continuous, and made up of an aggregation of organisms with nuclei, and much resembling amœbæ. This stratum is separated from another of identical structure by a chamber filled with water. The outermost layer has a multitude of pores, through which the supply of food and oxygen enters. The floor of the lower and thicker layer has a number of orifices opening into tubes which widen out into globular caverns a little below the surface. The sides of these globules are studded with amœba-like organisms, each having a cilium, or appendage resembling an eyelash, which is constantly vibrating, and so establishing a current in a direction downward into canals which open into great, funnel-like, or crater-like orifices. These great orifices are the *exhalant* apertures, the pores *inhalant* apertures. The food and oxygen in the stream of water is appropriated by the sponge-organisms individually as it flows by.

When placed under the microscope, the living sponge is a wonderful sight. Dr. R. E. Grant, who was the first to witness it, having put a small branch of living sponge, with some sea-water, into a watch-glass, saw a "living fountain vomiting forth from a circular cavity an impetuous torrent of liquid matter, and hurling along, in rapid succession, opaque masses, which it strewed everywhere around." Here is a circulation of water answering the same purpose as that of blood in other animals. The sponge takes in food and oxygen through its minute pores, and voids the waste matter through the oscula, or larger orifices. In the *Spongia fluviatilis*, or fresh-water sponge, the pores are not permanent, but they appear and disappear without leaving a trace behind, as in the case of the amœbæ.

The spiculæ of the siliceous sponges assume sundry shapes, being sometimes straight, like needles; again headed and pointed like pins, or furnished with grapnel-like hooks at their ends, etc. Perhaps the most curious of all the sponges is the "glass-rope" (*Hyalonema*), which has the appearance of a rope of twisted glass fibres, with a fibrous sponge attached to one end. Another very interesting form of sponge is the *Euplectella speciosa*, or Venus's flower-basket, which grows in the shape of a cornucopia, and is composed of fine glossy threads of silica.

The best sponges for toilet use come from the Ægean, and are found in about eight fathoms of water. They are gathered by divers. A coarse quality of sponge is found on the coasts of Florida and the West Indies. These are gathered with long-hafted forks. To remove the sarcode, the sponge is buried for some days in the sand, until the animal matter rots, and then the horny keratose is soaked and washed.

Jute-Paper.—One day's issue of the Dundee (Scotland) *Advertiser* was recently printed on paper made of jute. The material is said to be of good, firm quality, though thin and transparent, and of a yellowish tinge. The chief objection hitherto urged against jute-paper is its dark color; and, if, as appears probable, this can be obviated, there is no doubt that jute-paper will quickly supersede that made from rags, except for the best qualities. The jute employed in this instance is old bagging, which commands but a low price. As an encouragement to inventors, the proprietors of the *Advertiser* offer a premium of £50 for the best ream of paper made entirely from jute, of the size and weight of the paper on which the

journal is usually printed, the maker undertaking to supply 50 tons at a price not exceeding 4½*d.* per lb.; and a premium of £100 for the best ream of paper made entirely from jute, in size and weight as above, the maker supplying 100 tons at 4*d.* per lb. Old jute bagging may be bought in any quantity, in Dundee, at £9 10*s.* per ton.

Facts for Spencer.—Some striking illustrations of governmental negligence are given in the *Lancet*, in an article on "Army Medical Services." The writer states that in the armies of the first French Empire there was one surgeon to each 130 men. The French troops sent to Algeria in 1830 had only six surgeons to each 1,000 men. In the Crimean War the proportion was less than one (0.72) per 1,000. Throughout the war, the average number of patients under the care of each surgeon was 300. In the Italian War affairs were about as bad—less than one surgeon per 1,000 men. After Magenta, each surgeon had 175 wounded men, and after Solferino 500 under his charge. If he devoted 2½ minutes to each case, every moment of 24 hours would be taken up. The writer refers in terms of commendation to the medical and sanitary service of the United States during the late War of Secession. During the war between Austria and Prussia, 26,000 wounded of both armies were left, after the battle of Königgratz, totally without medical assistance, and unsupplied with food or water. The French army in the late war with Prussia had only two medical officers per 1,000 men, but 4½ veterinary surgeons per 1,000 horses!

A Singular Race.—A French traveller, M. Duveyrier, describes, in "Ocean Highways," a curious race, the Imôhagh (called in our maps Tauricks or Tuâregs), who dwell in the heart of the Sahara. They are pure Berbers, with white skin, but their uncleanly habits give them the appearance of blacks. The men alone wear a thick black veil over the face, while the women dispense with that covering. A man would consider himself dishonored were he to expose his face, and he takes precaution against any involuntary breach of decorum, by wearing his veil at all times, whether sleeping, walking, fighting, riding, and even speaking to his father. As a general rule, the Imôhagh despise fire-arms, as fit only for cowards, "but they fear thêm extremely" remarks M. Duveyrier.

They treat their women with great respect. No Imôhagh woman would consent to her husband indulging in plurality of wives; and, what is perhaps more singular still, the women alone know any thing of the art of writing. In political affairs the weaker sex exercise a powerful influence; and, when a chief dies, the supreme authority descends to the eldest son of his eldest sister.

Reproduction of Eyes in Crawfish.—That the crawfish has the power of reproducing an eye which it may happen to lose is a fact quite familiar to naturalists, but we are indebted to M. S. Chantran, of the French Academy of Sciences, for the discovery that this power of reproduction varies according to the animal's age. In a recent number of the *Comptes Rendus*, M. Chantran gives the results of his observations on this subject, from which it appears that a crawfish one year old quickly and effectually repairs such injuries, while in animals two or more years old reproduction is uncertain in its operation, and never perfect. His first experiment was with a number of one-year-old animals. In October, 1871, after the close of their moulting season, he clipped off their eyes. Moulting commenced in May of the year following, and in September, after four months, the eyes were perfectly reproduced.

The next experiment was with animals two years old. These he deprived of their eyes, either immediately before moulting set in, or in the interval between two moults. The results in these cases were various. In some of the animals, after three or four months, the eyes were reproduced, but then the pupils were so disfigured as to leave it doubtful whether they could serve for the purpose of vision; in others, one pupil was considerably smaller than the other.

Finally, in the case of full-grown animals, which moult less frequently—the females but once a year, and the males twice—the author's results did not show any re-

production of the eye, but only the growth of *buds* marked with a black point, and, in one case, of opaque bifid buds in place of eyes. The author promises at an early day to communicate to the Academy his observations on certain concretions formed in the stomach of the crawfish, and called *crab's eyes* in old pharmacopœias.

The Amarantus Blitum.—M. Boutin's observations on the *Amarantus blitum*, briefly alluded to in a late number of the MONTHLY, are so important as to call for a fuller statement. The amarantus belongs to the order *Amarantaceæ*, which contains nearly 300 known species. Some of these are familiar annuals in flower-gardens. The *Amarantus blitum* is a weed growing abundantly in many parts of Europe, and has never hitherto been supposed to possess any properties of economical value. Boutin's attention was first called to this plant on seeing it employed in scouring brass utensils. He supposed that it must contain some free acid or some acid salt. He found with surprise that it was completely neutral, and contained only nitrate of potash (saltpetre). To determine the proportion in which this salt enters into the constitution of the amarantus, he reduced to ashes 100 grammes (between 3 and 4 ounces) of the dried plant. The 16 grammes of ashes were treated with warm distilled water, and the whole then thrown into a filter. Having washed well the insoluble portion which remained in the filter, the author evaporated the filtered liquid, and so obtained a residue of carbonate of potash, 8 grammes. This weight of the carbonate is the equivalent of 11.68 grammes of the nitrate of potash, or saltpetre. The insoluble portion remaining in the filter would, on desiccation, give a weight equal to that of the carbonate obtained, or 8 grammes, to make up the original 16 grammes of ash. This insoluble portion consisted of lime, oxides of iron, alumina, and silica, with a small amount of phosphate of potash.

The author remarks upon the importance of this plant as a manure. It is superior to guano. And, if from any cause the supply of nitre for the manufacture of gunpowder were cut off, this plant could readily furnish it in any quantity. The question now arises, whence does the amarantus directly derive its nitrogen—from the soil or from the atmosphere? In the spring of 1872 the author had a plot of ground broken up with the spade, to a depth of about 8 inches, and kept free from all vegetal growth during the entire summer. This ground was in a condition to receive all the nitric acid and ammonia produced in the atmosphere by electricity. Yet, on a very careful analysis, no appreciable quantity of the nitrate could be found. On the other hand, the amarantus growing in the immediate vicinity yielded the usual amount—10 to 12 per cent. of the dried plant. Hence the author concludes that plants derive their nitrogen directly from the atmosphere.

Discovery of Ancient Egyptian Mines.—Some of the iron-mines anciently worked by the Egyptians have recently been discovered anew by English explorers, and search is to be instituted for other ancient mines of silver, gold, and iron. As the processes followed in ancient times for the reduction of ores were very defective, it is expected that, in the *débris* accumulated in the neighborhood of the mines, an amount of the useful and precious metals will be found sufficient to make the working it over again profitable. At a recent meeting of the British Society of Antiquaries, mention was made of the discovery, in the neighborhood of Mount Sinai, of the turquoise-mines of the ancient Egyptians. The discoverer, an Englishman, whose name is not given, observed in the water-courses of that region, which in summer are dry, peculiar blue stones which he soon ascertained to be turquoises. This circumstance led to further research. We are now informed that, "aided by the friendly tribes he has taken into his pay, he has discovered the old turquoise-mines of the ancient Egyptians, the rocks that they worked for the stones, the very tools they used, and their polishing and grinding places." The fortunate discoverer has already sent to England some of the finest turquoises ever seen.

While searching for the turquoise-mines, this same explorer discovered the ancient lines of fortification surrounding the works, and came upon the remains of vast iron-works, which must have employed many

thousands of hands. Slag taken from the refuse-heaps around these works contains as much as 53 per cent. of iron. The whole surrounding district is well worthy of being thoroughly explored by the antiquary, as it contains many hieroglyphic inscriptions which would doubtless throw much light upon the early history of metallurgy.

The Sack-Tree.—A notable tree is the *Antiaris saccidora*, or sack-tree, of Western India, the inner bark of which forms a very good material for sacking, and also for cordage. It often attains a height of 100 feet, with a diameter of six. The native method of making sacks of this material is very simple. Usually a tree about one foot in diameter is chosen, and from this a section of the length desired for the sack is cut. This log is steeped for some time in water, in order to soften the bark, and is then beaten all round with clubs. In this way the outer bark is removed, and the inner detached from the wood and rendered soft and pliable. Next it is folded over on itself at one end, after the manner of skinning a squirrel, and so turned inside out. All that is now required to complete the sack is, that one of the ends be sewed up, which is readily done. But a sack may be made without stitch or seam. This is done by arresting the process of *skinning* some two or three inches above the farther end of the log, and then sawing off the latter at that point. The sack has then a solid wooden bottom.

These sacks are extensively used in Western India and Ceylon, and serve their purpose very well. The same material is sometimes employed in the manufacture of clothing, and for paper-making. To prepare it for the former purpose, the bark is stripped off in pieces, which are then thoroughly soaked and beaten out till the texture becomes white and rough like fur. It is then cut according to the required shapes, and stitched together.

Substitute for Quinine.—The employment of carbazotate of ammonia (ammonia combined with carbazotic, picric, or trinitrophenic acid) has been suggested as a substitute for sulphate of quinine, and Dr. Beaumetz, of the Société Thérapeutique de Paris, gives the following as the result of his employment of this salt: Case 1, quotidian ague. Daily dose one to two centigrammes in pills. Recovery in 4 days. Case 2, quotidian ague. Complete recovery in 5 days—five pills used. Here sulphate of quinine had been used without effect. Case 3, tertian. Recovery after 8 days—two pills a day. Case 4, quotidian. Recovery after 8 days. Case 5, facial neuralgia. Speedy recovery. Case 6, tertian, recovery in 2 days. Dose about one grain (6 centigrammes). Sulphate of quinine had been given for 17 days, without effect. Dr. Beaumetz hence draws these conclusions: the carbazotate is very efficacious in intermittent fever, and the paroxysms may be suppressed by the use of 2 to 4 centigrammes ($\frac{1}{3}$ to $\frac{2}{3}$ grain) daily. In these doses the drug appears to be innocuous. Its physiological action resembles that of sulphate of quinine.

NOTES.

THERE is in Cayenne a fly, called the *Lucilia hominivorax* (man-eater), which commits great havoc among the convicts sent out to that colony by the French Government. M. Charles Coquerel says that this fly lays its eggs in the mouth or nostrils of a sleeping convict, especially a drunken one, and that the offspring in their larval state usually bring about the death of their victim.

THE following curious statement comes to us on reliable authority: A vicious horse (gelding) that had the singular habit of striking violently with his fore-feet, especially when being shod, was for several years worked with a mare that during the time bore a colt. This colt, when quite young, developed the habit peculiar to its mother's mate, becoming violent when any attempt was made to handle its fore-limbs. The habit increased with the colt's age, and, on being shod the first time, its manner of striking was observed to be precisely like that of the horse. The mother of the colt was unusually kind and gentle.

A STATEMENT of some interest occurs in *Scribner's Monthly*, showing the increasing demand, among the reading-classes of New York, for works of a scientific character. The writer compares the number of books called for at the Astor Library, in the literary and scientific departments respectively, during the three years 1865, 1871, and 1872. In the first of these years, 18,896 scientific works were called for by readers, and 26,070 literary; in the second, 33,428 scientific, 58,595 literary; in the third, 55,660 scientific, 55,657 literary.

In his late work on the "Physiology of Circulation," Dr. Pettigrew gives the following as the rate of the heart-beats in man at different periods of life: In the human fœtus the heart beats 140 times per minute; at birth, 130; second year after birth, 100; third year, 90; fourteenth year, 80; middle age, 70; old age, 60, or even less. The variation in the frequency of the beat of the heart in the lower animals is still more remarkable.

From the United States statistics, it appears that the percentage of insanity, idiocy, etc., is greater among the white population of this country than among the black. Thus, among the whites, one in 2,253 is deaf and dumb; among the colored race (blacks and mulattoes), only one in 3,780; insane whites, one in 943; colored, one in 2,750; idiotic whites, one in 1,575; colored, one in 1,530. The statistics of blindness, however, are more unfavorable for the colored race: blind whites, one in 2,000; colored, one in 1,469. The insane females, both white and black, outnumber the insane males, 19,202 against 18,179; but the male idiots are greatly in excess of the female—14,476 against 10,046.

There is found in Bombay a minute variety of ants which surround their nests with a series of concentric circular walls an inch or an inch and a half high, and about the same distance apart, the innermost wall being the highest. The object of these walls or fortifications is not yet known.

During a botanical exploration of the region around the river Coanza, in Lower Guinea, Dr. Welwitsch's party found their supply of provisions exhausted. The men accordingly went in search of food, with senses quickened by hunger. They were so fortunate as to discover an enormous mushroom, as large as an umbrella, which made soup enough to satisfy the hunger of 20 men. This specimen was the first of the species seen by Welwitsch, but subsequently he often met with it, and learned that these great mushrooms are brought to market at Pungo Adongo by the natives, and there sold at from one to three pence each, according to size.

By act of Parliament of the year 1843, mechanics' institutes, literary and scientific associations, and the like, were exempted from local taxation in England. The Government now proposes to do away with the exemption, thus imposing a tax on knowledge. If the measure succeeds, many societies must close their doors, and the work of popular education will receive a serious check.

A "memorial volume," to commemorate the services rendered to science by the late Prof. Liebig, is to be published by the Royal Bavarian Academy of Sciences, of which body he was president. The volume will contain an obituary notice of the deceased, and three separate dissertations upon the services rendered by him to physiology, agriculture, and theoretical chemistry, to be written by Profs. Bischof, Vogel, and Erlemeier.

The amount of tobacco paying duty and cleared for consumption in Great Britain steadily increases. Thus in 1841 it averaged 13¾ oz. per capita; in 1851, 16¼ oz.; in 1861, 19½ oz.; and in 1871, 21½ oz.

The average number of persons per house, in various cities of the United States, is as follows: New York, 14.72; Cincinnati, 8.81; Brooklyn, 8.64; Boston, 8.46; Jersey City, 8.37; Hartford has 5.56; Rochester, 5.36; and Toledo, the lowest, 5.20. The densest population is that of the Fourth Ward, New York, where there are 24.61 persons to each dwelling.

The Russian Government is about to construct a railroad from Nijni-Novgorod on the Volga, to the Japan Sea, about 4,200 miles. This line, in conjunction with that from Nijni-Novgorod to St. Petersburg, will connect the Baltic Sea with the Pacific. The road will run east in latitude 56°, 850 miles to Tobolsk, crossing the Ural Mountains. From Tobolsk it will take a southeast course 1,500 miles to Irkutsk, on Lake Baikal (latitude 53°). The remainder of the route is not yet determined on, but it is expected that work will be commenced on the western end during the present year.

Lake Neahtawanta, near the Oswego Falls, is a noted fishing-ground, containing abundance of pickerel, pike, perch, bass, and indeed nearly all the fresh-water fish. But a sort of epizooty recently broke out among the pickerel, which threatens to utterly destroy all the fish of that species contained in the lake; indeed, it is believed that they are already destroyed. The other fish in the lake are not affected by the disorder.

Dr. Lyon Playfair has no very high opinion of the value of English university education. He said recently in Parliament that "a Scotch university teaches a man how to make a thousand a year, an English university how to spend it."

Mr. Benjamin Smith, of London, has sailed for the north-pole in the yacht Diana. Mr. Smith expects to join his supply-yacht, the Samson, at Cobbe's Bay, on the northwest of Spitzbergen, latitude 80°. From that point he will push as far northward as the ice will permit. He purposes returning home in one year at the farthest.

PROF. JOHN TORREY.